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THE SCIENTIFIC MONTHLY

MAY, 1920

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN[1]

By Professor JOHN C. MERRIAM

UNIVERSITY OF CALIFORNIA

PLEISTOCENE STAGES IN HUMAN HISTORY SUBSEQUENT TO THE TIME OF HEIDELBERG MAN. III.

THE earliest remains of man, known in the *Pithecanthropus* of Java and the Heidelberg type, are generally considered to represent stages of time not ranging far from the beginning of the Pleistocene period, or the geological division immediately preceding the present. It has been suggested that *Pithecanthropus* is of Pliocene age. The Heidelberg jaw was considered by Schoetensack to be possibly Pliocene, but is presumably not older than early or middle Pleistocene. With the exception of these two cases, the numerous occurrences of human remains found in deposits antedating the beginning of the present geological period are all generally considered to be of middle to late Pleistocene age.

Excepting a few widely scattered occurrences, ranging from Australia through Asia and Africa, the collections representing Pleistocene man have been secured from formations of western Europe, and discussion of the next stages in human history is as yet mainly concerned with early man in Europe. This record fortunately occurs in a division of the geological story to which extraordinarily close attention has been given by reason of the interesting fluctuations of climate marking this portion of time. Before proceeding with a discussion of the occurrences of human remains and the nature of the evolutionary sequence, it is desirable to sketch in a preliminary way an outline of the climatic and geographic history of this period, in

[1] Delivered before the National Academy of Sciences in April, 1918, as the sixth series of lectures on the William Ellery Hale Foundation.

Geological Periods	Climatic Stages	Cultural Stages	Human Types
Recent	Postglacial	Age of Metals Neolithic	Modern Races
Pleistocene	4. Glacial	Palaeolithic: Azilian, Magdalenian, Solutrean	Cro-Magnon
	Interglacial	Aurignacian, Mousterian	Neanderthal
	3. Glacial	Acheulean, Chellean	
	Interglacial		Heidelberg
	2. Glacial		
	Interglacial		
	1. Glacial		
Pliocene		Eolithic	Pithecanthropus

FIG. 1. TABLE ILLUSTRATING RELATION OF STAGES IN HUMAN EVOLUTION TO DIVISIONS OF GEOLOGICAL TIME.

which we find man passing through some of the most significant stages in the whole course of his evolution.

FLUCTUATIONS IN ENVIRONMENT OF PLEISTOCENE MAN IN EUROPE

The story of glacial history in Europe corresponds closely with that of America, and is too well known to require more than the general statement that during at least four stages in this epoch, climatic conditions were of such a nature that accumulation of snow and ice in enormous quantities was permitted at altitudes far below the present snow line. The extent to which the climate differed from that of the present time varied for the several glacial stages, but in the most extreme advance ice seems practically to have covered the northern half of Europe, extending over the British Isles and across the continent through Belgium, Germany and Russia. Ice also reached down from the Alps and other ranges to levels much below those at present touched by glaciers. Between the ice epochs, the

climatic pendulum, swinging in the return beat, brought conditions in some cases more closely approaching those of the warm temperate regions than we find represented in the present climate of western Europe. It is important to note that it was in this time of frequent and radical changes in climatic conditions, and therefore of variation in the whole environment, including animal and plant life, that the present high level of human evolution was attained.

In the period of climatic changes of Pleistocene time the form of the land and distribution of water of the European region also varied much. Particularly in and near the second and third interglacial stages the British Isles and Iceland seem to have been connected with the mainland in the region of France and Belgium; the North Sea was dry, and land extended across from Scandinavia to England. During this period, the boundaries of the sea were in general moved farther out along the borders of the continent than at the present time. There seems also to have been land connection between Spain and northern Africa and between Africa and Italy.

During this period, we find not alone the climatic and geographic conditions subject to modification, but the whole scheme of animal and plant life shifted greatly from stage to stage. As would be expected, during the cold periods waves of migration swept across the continent of Europe from the north, and the Arctic animals extended their range to the lower lands; while during the stages of warm climate southern life reached north to England and middle Europe. Not only was the life shifting through migration of climatic zones, but great groups of species in many divisions of the animal and plant world disappeared, giving place to forms not known in previous time. These in turn became extinct and were largely replaced by new types before the beginning of the present geologic day.

DEPOSITS CONTAINING REMAINS OF LATER PLEISTOCENE MAN IN EUROPE

The geologic record of Pleistocene time out of which we read our human history is obtained from a great variety of evidences, including the accumulation of deposits in seas, lakes, rivers, and upon the land. It is read also from physiographic records shown in the sculpturing of land forms by wind, water, and ice; and in the history of a continuously changing living world, both plant and animal. The sequence of deposits in which entombed organisms have been discovered is complicated and difficult to read. It is moreover not the same record

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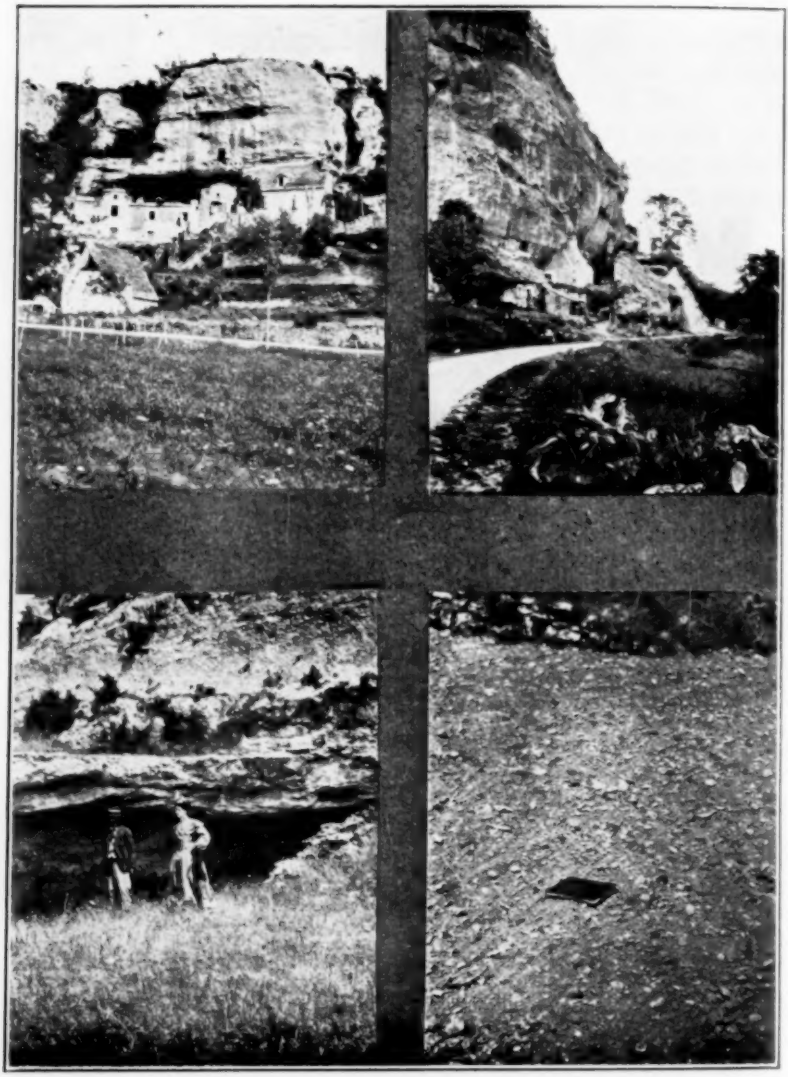


4 5

FIGS. 2 TO 5. CAVE DWELLINGS IN THE VEZERE VALLEY, FRANCE. Fig. 2, Cave adapted for modern home. Fig. 3, Laugerie Haute, a modern dwelling on the site of cave deposits representing the stage of Cro-Magnon man. Fig. 4, Cave at Le Moustier, with deposits of Neanderthal stage. Fig. 5, Floor of Le Moustier covered with flaked flints.

in all localities. Correlations or comparisons between widely separated regions are made with difficulty. It is, nevertheless, true that with the combined use of all known agencies, includ-

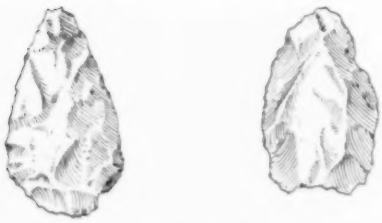
ing the thermometer of climate in glacial history and the record of evolution shown in plants and animals, it has been possible through what amounts to international cooperation to work out a history with some degree of satisfaction.

The human remains of greatest significance in Europe have been found in deposits of two kinds, one consisting of stream accumulations of clay, sand, and gravel; the other the piling up of earth, gravel, sand, and stalagmite deposits in caves.

The relative age of stream deposits, and of their entombed remains, may be determined by the sequence of layers resting one upon another in a single area; or may be indicated by a succession of terrace deposits representing remnants of accumulated strata left stranded in the cutting of a valley. In general, we may not expect the best records of man to be found in formations made by streams. Although traces of skeletons are met occasionally, the destructive action of a stream is generally pronounced. Remains of implements, especially those of stone, being more resistant than skeletons, are better known in stream deposits.

The most important source of human relics of Pleistocene time is found in the numerous caves of limestone formations in western Europe. Caverns have always been places of abode for many groups of higher animals, furnishing as they do shelter from the weather and protection against enemies. Caves have been unusually significant in study of the life of early periods because they have served as concentration points for the remains not merely of their owners, but of the whole range of other animals supplying food from the surrounding country. Cave deposits are also of exceptional significance for the reason that in limestone regions, lime-burdened water dripping from the roof upon bones or other relics has often encased them with a calcareous or stalagmitic covering.

Man like other creatures seems early to have learned the advantage of cavern life. In the cave he also accumulated heaps of bones representing the animals upon which he preyed, and his bones like those of other animals were entombed in earth, clay, gravel, and stalagmite deposits in the floor of the room that was once his home. In our search for evidence concerning the history of man in the long period through which he worked his way up to domination of the natural world, no information has been found to exceed in interest the records held for ages in safe keeping in the caves. A story of the beginning history of our race comes to us from these sources filled with the thrill of adventure, and showing always the upward striving of becoming man.



FIGS. 6 AND 7. FLAKED FLINTS OF THE RIVER DRIFT STAGE. Adapted from Reinach.

RIVER DRIFT MAN

In the divisions of the geologic record succeeding those from which we have obtained *Pithecanthropus* and the Heidelberg man there are several stages at which relics apparently representing human handwork have been found without accompanying skeletal evidence of man himself. Such remains are the flaked flints of Chellean and Acheulean types discovered especially in stream deposits of the Somme Valley in northern France and in the south of England. These objects are found in deposits evidently younger than those from which the earlier eoliths are obtained and show clear evidence of purposeful shaping. They are flaked in such manner as to leave no doubt concerning the influence of an intelligent creature like man in their forming. They were evidently produced by beings of the human type inhabiting Europe subsequent to the time of Heidelberg man and before the stage of the typical Neanderthal race.

NEANDERTHAL MAN

Following the stage of Heidelberg man the earliest human relics of which we have evidence in skeletal characters are those representing the Neanderthal race. This type is now well known by skulls and other skeletal parts from numerous cave deposits of western Europe. With these remains there have been found also abundant traces of implements and of the contemporaneous animal life of this period. The materials available have made possible a very satisfactory interpretation of the physical characteristics, industry, mentality, and environment of the race.

The Neanderthal type has been best known by a now famous skeleton obtained in 1856 in a cave near Düsseldorf. Other specimens of similar type are the Gibraltar, Spy, Chapelle-aux-Saints, and Le Moustier remains, together giving full opportunity for interpretation of the characters of this remarkable race. All of these skeletons represent beings distinctly human, and with moderately large brains, but possessing exceedingly

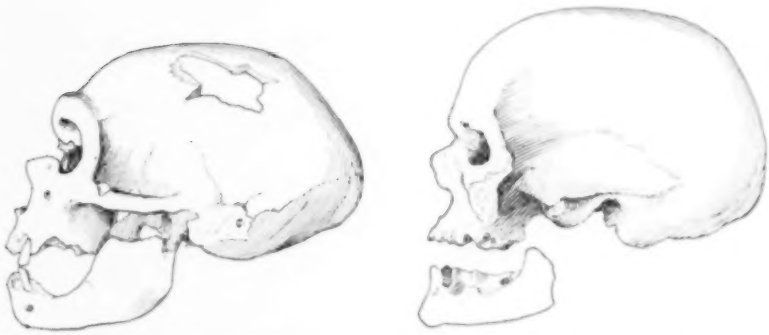


FIG. 8. SKULL OF NEANDERTHAL TYPE FROM CHAPELLE-AUX-SAINTS, FRANCE, × ⅓. Adapted from Boule.

FIG. 9. SKULL OF CRO-MAGNON MAN FROM LES EYZIES, FRANCE, × ⅓.

low and generally depressed skulls with extraordinarily large ridges over the eyes.

Associated with the remains of Neanderthal man in the cave deposits at various localities there have been found great quantities of flaked flints which were evidently the characteristic implements utilized by this race. In the famous cavern at Le Moustier enormous numbers of flints are known, of which some are discarded implements and others are probably the byproducts of implement manufacture. They all indicate a stage of development in which the flaking is sufficiently advanced to give a clean, sharp cutting edge undoubtedly used for a wide variety of purposes.

In the same deposits with the remains of Neanderthal man, and with the relics of his culture, there are found abundant skeletal parts of the animals of the surrounding region which provided food and probably clothing. Other animal remains found in the caves may have been accumulated by carnivorous mammals occupying these shelters in intervals between periods of human habitation. From the evidence available we know

FIGS. 10 AND 11. FLAKED FLINTS FROM FLOOR OF THE CAVERN OF LE MOUSTIER, × ½.

FIGS. 12, 13 AND 14. COMPARISON OF SKULL OF NEANDERTHAL MAN WITH A CHIMPANZEE, TO THE LEFT, AND A MODERN MAN, TO THE RIGHT.

that Neanderthal man was associated with the reindeer, woolly rhinoceros, woolly mamoth, horse, stag, giant deer, bison, cave bear, cave lion, and cave hyena. A large percentage of these animals are now extinct and are characteristic of the later Pleistocene of Europe.

In many respects the Neanderthal type presents the most striking illustration of connection between the later stages of human evolution and the history of mammalian groups which in their development trend toward man in the distinctly prerecent portion of the record of life. The history of the Neanderthals lies well within a geological period distinctly separated from the present, the environment of this man was physically and biologically a world differing from the present, and the man himself differed markedly from any existing race. In very many ways the Neanderthals express that remoteness of time, difference of surroundings, distinct difference of physical char-

FIG. 15. RESTORATION OF NEANDERTHAL MAN. Drawn by Frieda Lueddemann, under the direction of the author.

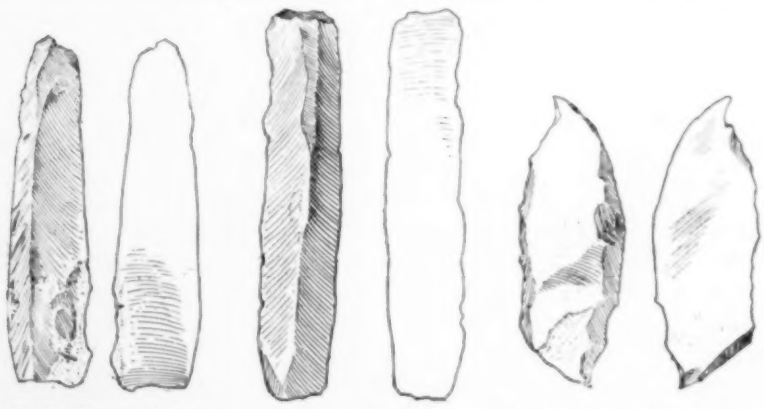
acteristics, inferior level of industry, and limitation of mental development, which one might expect to find somewhere between *Pithecanthropus* and modern races if the existing human group represents progressive development out of a more ancient and less human stock.

CRO-MAGNON MAN

At numerous localities in western Europe we find abundant evidence that a type of human being differing widely from the typical Neanderthals occupied this region between the time of Neanderthal man and the present epoch. These remains are found in cave deposits, and like those of the Neanderthals are associated with abundant implements and with the remains of a wide variety of animals which as their contemporaries furnished food and clothing.

The history of this later type is known in several stages, of which one of the most important is that represented by the famous Station of La Madeleine, only a short distance from Le Moustier on the Vezere River in the French province of Dordogne. The skeletal remains of this race generally represent individuals of large size, with skulls corresponding in outline to highly developed types of the present period. The brain case, like that of modern man, has a large content, and the form of the brain corresponds to that of the vigorous mental types of the present day.

Judging from physical characters alone one could not avoid the conclusion that this Cro-Magnon type represents a form of man skilled in thinking and in the expression of thought through action. It is, therefore, not surprising to find associated with this race a wide range of beautifully formed implements shaped



FIGS. 16, 17 AND 18. TYPICAL MAGDALENIAN FLAKED FLINTS FROM THE STATION OF LA MADELEINE, FRANCE, $\times \frac{1}{2}$.

from stone and from the bones of animals hunted. The stone implements show an advance in the art of chipping or flaking developed in various forms, some delicately flaked, others giving long clean-cut lines and sharp edges. Implements of bone and antler are abundant and rival in their form and ornamentation the beautiful carvings of modern Eskimo. We find also on implements and on fragments of bone and antler extraordinary expressions of an artistic instinct represented in drawings of the contemporary animals and even of people. These illustrations show us the reindeer, the mamoth, and the bison, as living creatures fully known to Cro-Magnon man and pictured by him in characteristic attitudes of action. Even more remarkable if possible are the wonderful series of drawings and paintings left by this race on the walls of many caves which were evidently not habitations but served some mysterious purpose not yet fully understood.

The remains of animals associated with the Cro-Magnons include reindeer in abundance, horses, the woolly elephant, woolly rhinoceros, cave bear, lion, and many other creatures representing a fauna in large part extinct, and of which the

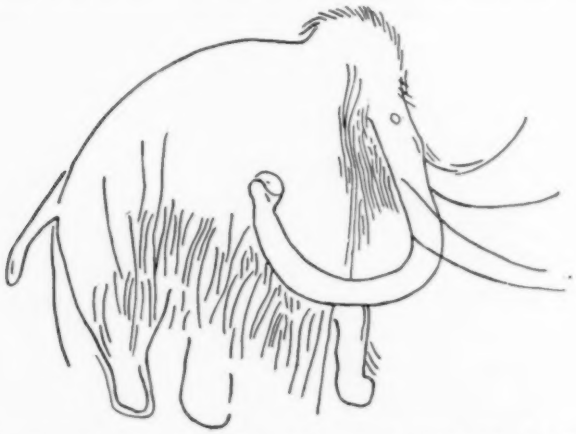


FIG. 19. REPRESENTATION OF THE WOOLLY ELEPHANT, DRAWN ON THE WALL OF THE CAVE OF COMBARELLES, LES EYZIES, FRANCE. Adapted from Capitan and Breuil.

FIG. 20. PAINTING OF THE WOOLLY RHINOCEROS ON THE WALL OF THE CAVE OF FONT-DE-GAUME, LES EYZIES, FRANCE. Adapted from Capitan and Breuil.

FIG. 21. RESTORATION OF CRO-MAGNON MAN. Drawn by Frieda Lueddemann under the direction of the author.

surviving types are known principally from regions outside western Europe.

In physical development, and apparently in mentality, the Cro-Magnons approached closely the characteristics of modern man. This race represents in western Europe the beginning of modern life taking its origin in ancient times. The Neanderthals go far in physical characters, in mentality, and in environmental setting to bridge the gap between modern man and the earliest humans. The Cro-Magnons show us that even the modern cast of physical development is rooted deeply in the remoteness of an early geologic day.

SIGNIFICANCE OF DATA BEARING UPON THE PROBLEM OF HUMAN ORIGIN

Passing in review the stages in evolution of man, it is desirable to note once more the evidence of geological succession of the four human types already discussed, and with this to state that all four were present on the earth before the beginning of the present period. The proof of their antiquity seems especially striking when we consider that between the time of appearance of the third or Neanderthal type and the present day events of great geological and biological significance profoundly changed the face of nature, and that after the Neander-

thals had become established in this region a period of fifty thousand to two hundred thousand years probably elapsed before the modern races became dominant.

It should be noted again that remains of the later stages, including Neanderthal, although apparently absent from the New World, seem widely distributed over Europe, Asia, and Africa. The first two stages, represented by *Pithecanthropus* and Heidelberg man, are known by single occurrences, and the one generally assumed to be the earlier is situated in a region known to be an area of evolution of the anthropoid group.

We have also seen that the series shows us, in passing backward through it, a reduction in brain capacity, increase in the prominence of the face, and a general taking on of anthropoid characters, until the earliest form is recognized as unquestionably of all human types the one standing nearest to the apes, and yet apparently distinguished from anthropoids by its specialized human limbs.

While the evidence is incomplete, the record as it stands agrees down to extraordinary detail with the expectation which one might have of early human history based upon the view that man, while a derivative of the anthropoid group, is now widely separated from all simian types, and has presumably required long ages in which to reach his present stage of differentiation away from the primitive stock.

The earliest occurrences are at the geographic point where we would expect to find them. The earliest types represent approximately the stages of evolution that the paleontologist would anticipate discovering in the strata from which they have been recovered. The later history shows a gradual modification at a rate corresponding in general to that seen in history of other groups of mammals. We note also that the family seems to spread itself gradually over the world, and as nearly as we can determine, with this wider distribution there begins the differentiation into distinct types or species characteristic of geographic provinces.

In a word, human history, so far as the development of physical or biological man is concerned, indicates that our origin is comparable to that of other organic groups, and that we are apparently an outgrowth from the mammal world subject to the same laws of evolution and differentiation as are expressed in myriads of other organic types. The existing races of man represent the morphological and geographical expression of this evolutionary history. Their characteristics are clearly the result of hundreds of thousands of years of differentiation. The

stamp that is put upon each type is the product of extraordinarily complicated influences in which inheritance and environment are essential elements. They are not fleeting impressions, but have significance comparable to that definiteness in organic type which leads us to expect the rose to beget roses, and lions to be the offspring of lions.

As was noted in the introduction to the first lecture, students of biological aspects of the human problem have recently called particular attention to the importance of race as weighing definitely in consideration of many world problems, along with the factors based upon differentiation of peoples according to linguistic stocks, ethnologic relationships, and social organization. This is not interpreted to mean that great significance does not attach to the group influence in peoples organized according to ethnologic characters, or by reason of the effect of language, or through many other causes. It does mean that factors of fundamental significance, resting upon basal characteristics of human nature, brought out in our long history, and represented now in race, have perhaps received less consideration than is their due. It means not only that a clear view of the human situation must present a picture showing the common generalized characters represented in practically all human types and individuals, but that with these we must see also the length and breadth, the height and depth of human differences. Unless this view is taken we shall fall short of the interpretation of humanity needed in order to give to every group, as well as to every individual, that full freedom to develop *its own peculiar talent*, and to grow into the fullest usefulness which we assume to be the natural right of all.

And finally, the whole trend of history within the chapter just read from ancient records exhibits without question a definite progressive movement of the human type. This is expressed in physical capacity for greater breadth of comprehension, and in wider range of activity and occupation given by coordination of the brain and hand as also of the brain and tongue. Man of the present day may read his story back to that early stage in which he first sees himself distinguished from the beast. He sees the beast made to a man-like beast and then a man. Perhaps to you the student of this ancient life has seemed to look upon a passing scene which might well have been left unknown—and yet to those who read what he who runs may see, the present world is brighter for the view—the future built upon the upward striving of the past must see the best there is in life at length prevail.

OCCUPATIONAL THERAPY IN TUBERCULOSIS[1]

A Critical Retrospect upon the Program of Physical Reconstruction as developed in the Military Hospitals for Tuberculosis

By FRANK A. WAUGH

CAPTAIN, SANITARY CORPS

THE reconstruction of disabled soldiers is something new. It had never been tried before the great war on any appreciable scale. Nevertheless all the leading nations in this war undertook extensive and systematic reconstruction almost from the start. Germany, France and England began the work promptly, and on a large scale. The success of their efforts was sufficiently plain, so that the United States coming later into the struggle, felt constrained to undertake something along similar lines.

There was some uncertainty for a time as to how and under what direction this work should be organized. The plan eventually adopted was for the preliminary work of the hospital period to be done by the Surgeon General's Office, while the more extended work of vocational retraining was deferred until after discharge from the hospital and the Army, and was placed in the hands of the Federal Board for Vocational Education.

A Division of Physical Reconstruction, with Colonel Frank Billings at its head, was therefore organized within the Surgeon General's Office, and definite work began early in 1918. One general hospital after another was manned and equipped, and finally the work, having proved its value, was extended to several base hospitals. The first of the tuberculosis hospitals to be regularly organized for this work was No. 16. Lieutenant-Colonel Alexius M. Forster, Comanding Officer, an experienced sanitarium man, had begun certain work along reconstruction lines, especially gardening, early in the spring of 1918. In July, Captain Frank A. Waugh arrived to take up the organization of a larger reconstruction service under direction of the Division of Physical Reconstruction in the Surgeon General's Office. For the next few months the reconstruction program

[1] Published under authority of the Surgeon-General, United States Army.

was expanded, adapted and readapted to varying needs as fast as experience showed the way and equipment could be found. Other Army hospitals handling tuberculosis were later organized for reconstruction work, including No. 8 at Otisville, New York; No. 17 at Markleton, Pennsylvania; No. 19 at Oteen, North Carolina; No. 21 at Denver, Colorado; Fort Bayard, New Mexico; and Whipple Barracks, Arizona.

It is the purpose of the present report to review, summarize, and criticize the work thus far done under the reconstruction program in the tuberculosis hospitals. It seems highly desirable to make a full record of this large and interesting experiment and to determine as accurately as possible just what has been accomplished, to know what parts of the program have proved successful and in what degree, as well as what items have failed and in what degree. This detailed criticism is all the more needful because of the fact that civil sanitoria for tuberculosis are particularly anxious to profit by the experiments made in the Army hospitals. The present discussion is based mainly upon the experience accumulated at General Hospital No. 16; but Hospital No. 8 and No. 19 were also visited (as well as several other Army hospitals not specializing in tuberculosis), and considerable help has been secured through correspondence with officers doing reconstruction work in Denver and Fort Bayard.

Specific Purposes

Several quite distinct motives have been influential in the development of the reconstruction program. These have not all worked together, but have operated differently at different times. Any fair understanding of the work must be based upon a clear conception of these objectives. Those which appear to have been the most influential may be summarized as follows:

1. *Return of Men to Military Duty.*—During the progress of the war this motive stood above all others. In Germany and France, particularly, special effort was made to redevelop for military service the largest possible proportion of disabled men. In American hospitals likewise the salvage of fighting men was earnestly sought. Much of the reconstruction work done prior to the armistice was directed to the training of men for further military or semi-military service. Instruction in the automobile shops, for example, prepared men for the Motor Transport Corps, and training in telegraphy was directed to the preparation of men for the Signal Corps.

2. *Vocational Reeducation.*—At the outset of the work in the United States probably the leading thought was the voca-

BEDSIDE WORK IN AN OPEN WARD. Bead-weaving—very popular and remunerative.

tional rehabilitation of disabled men. It was conceived that many soldiers would be so injured, especially by the loss of limbs or of sight, as to be incapacitated for their previous employments, and their retraining for new vocations was considered a prime duty of the government. Two important observations may now be made with reference to this idea: First the number of men requiring replacement in new vocations proved to be very much smaller than anticipated; Second, such vocational retraining, when necessary, can be more efficiently given after discharge from the hospital. In the United States the work of the Reconstruction Service of the Surgeon General's Office divides naturally from that of the Federal Board for Vocational Education precisely on these lines—a division which now seems wholly sound and sensible.

3. *Functional Restoration.*—Historically this was one of the earliest and strongest motives behind the program of physical reconstruction. In orthopedic practice it obviously plays a major rôle. In the treatment of tuberculosis, however, functional restoration is of such minor importance as hardly to be considered a direct objective at all. However the functional test which comes toward the end of the treatment period is in some sense restorative.

4. *Graduated Exercise.*—Perhaps the nearest approach to functional restoration in the tuberculosis program is found in the application of graduated exercise as a therapeutic measure. The therapeutic value of graduated exercise seems to be still a very much debated point among medical men. The case ob-

viously can not be reviewed here; but we may say briefly that, wherever and to whatever extent graduated exercise is brought into play, it fits immediately in to the general program of reconstruction.

5. *Functional Test.*—Many medical men who do not believe in graduated exercise as a form of therapy applicable to any stage of the tuberculosis treatment would nevertheless favor a functional test or try-out for cases apparently fully arrested, this test to be carefully given under medical supervision before the patient is finally returned to full military or economic duty. This test would take the form of graduated labor increased from day to day, as indicated, up to the point of a full day's work. Such a test also becomes a part of the reconstruction program.

6. *General Therapy.*—It should not require argument to show that the various activities grouped under the rather loose term of physical reconstruction are capable of assisting in the cure of patients in many indirect ways. As regards the treatment of tuberculosis, a special point may be made of the reconstruction contribution to the rest cure. Rest in bed and later in chairs in the open air constitutes the standard treatment; at least it is the one feature to which constant attention is required. Now it has been amply demonstrated that for convalescing

BUSY HOURS ON AN OPEN-AIR WARD. Reconstruction Aide in center; Nurse in background.

MAKING BASKETS AND TOYS ON THE OPEN PORCH IN THE SUN.

(non-febrile) bed cases and for all porch-chair cases the various forms of occupational therapy give more practical help toward the enforcement of the rest program than anything yet devised.

7. *Psychotherapy.*—Eminent tuberculosis specialists have laid much stress upon the mental attitude of the patient as a leading factor in treatment. While the value of this factor will doubtless be estimated differently by different men, all are likely to assign some importance to it. Experience shows that nothing does more than congenial occupation toward establishing an orderly state of mind, a healthy equanimity, an efficient self-control and a hopeful outlook toward the future. Results at this point have been so emphatic as hardly to leave any room for question.

8. *Morale.*—There is to be considered further the question of social psychology or the morale of the whole community. In the Army hospitals morale has been a critical factor, and it is certain to play some part in every sanitorium or colony. And we may say without hesitation that well-directed occupation for the hands and minds of patients does much to maintain morale.

9. *General Education.*—In the programs devised for the Army hospitals, general education early became a leading feature. The principal reasons for this were three: (*a*) The occupation of the patient's mind with interesting studies is fre-

quently the simplest form of occupational therapy; (*b*) The extraordinary and unexpected deficiencies in general education revealed in the Army made it seem a public duty to seize every opportunity for improvement; (*c*) Especially the illiterate element, which reached alarming figures, seemed to call for heroic measures of correction. Beyond these cases lay a certain number of men of better education who were glad to take advanced studies in commercial, scientific or semi-professional lines. The work in general education therefore developed to considerable proportions in the Army hospitals.

10. *Americanization.*—The alien soldiers, of whom there were vast numbers, presented a most serious special problem. Some of these were wholly illiterate, others could read their native languages but could not read English, practically all of them were very imperfectly schooled in elementary branches and dangerously ignorant of American institutions. It could hardly be denied that the government of the United States owed a special duty toward these men, and had a special need to protect itself by the Americanization of all such men to the utmost. A carefully planned and intensive effort was made therefore toward this end.

THE RECONSTRUCTION STAFF

In each of the general and base hospitals designated for the

HANDCRAFTS FOR BED PATIENT.

TELEGRAPH SCHOOL ON AN OPEN-AIR WARD.

reconstruction work a special staff was organized under direction of the Division of Physical Reconstruction. The staff was made up of four classes:

(*a*) Commissioned officers (those specially selected for this work being commissioned in the Sanitary Corps).

(*b*) Enlisted men, Medical Corps, specially chosen for educational or technical qualifications and taken by voluntary induction from deferred draft classifications. (A large proportion of these men were eventually given a noncom status).

(*c*) Reconstruction Aides, women specially trained in crafts or as teachers, and having a rather anomalous status somewhere between that of an Army nurse and a civil employee.

(*d*) Civil employees, both men and women, used in a great variety of duties.

METHODS EMPLOYED

In pursuit of the various objectives already set forth a great variety of expedients were adopted. Many methods were tried, with varying success. A review of the principal experiments seems necessary at this point.

1. *Vocational Teaching* in very mild forms was attempted at General Hospital No. 16 in gardening, poultry culture, telegraphy, typewriting, woodworking and automobile mechanics. For this work the personnel was good, the physical equipment meager.

2. *The General Schools.*—Small groups, mostly placed on wards and porches, were organized for instruction in general subjects, such as reading, writing, arithmetic, history, bookkeeping, drawing, French, etc. The instructors in these schools were of rather extraordinary caliber.

3. *Americanization School.*—A special school was organized to assist in the Americanization of foreign soldiers and particularly to secure the actual naturalization of every fit alien. This work was facilitated by special act of Congress. At No. 16 the Chief of the Reconstruction Service was also made Chief Naturalization Officer, thus coordinating the two undertakings. First of all every effort was made to teach every alien soldier to read and write the English language. All these men were then taken into a class in civics which met daily with a particularly competent instructor. The central feature of these daily meetings was open discussion of phases of government in which the patients themselves had had experience, *e. g.*, the post office and what it does, the policeman and his duties, the health department, the Army draft, the American school system, etc. The purpose of this instruction was to lead the men to see what American institutions are like, how they are man-

AUTOMOBILE SHOP—THE WORK CONDUCTED OUT OF DOORS IN THE SUNLIGHT.

A GREEK PUPIL; ILLITERATE, LEARNED TO READ AND WRITE AND BECAME AN AMERICAN CITIZEN.

aged and what is the real spirit of American government behind them. Finally these men were examined by a special agent of the Naturalization Bureau, were taken to the Federal Court by their instructors and given the papers which made them full-fledged American citizens.

4. *Individual Instruction.*—A considerable number of patients who could not, for one reason or another, come into these school groups were given daily instruction on their home wards by enlisted men or reconstruction aides. This work was reasonably efficient.

5. *Crafts Teaching.*—As the reconstruction program developed the largest single enterprise was the teaching and supervision of handcrafts on the wards. This work was wholly in the hands of reconstruction aides. The most popular crafts were hand weaving (colonial mats), rake knitting, bead weaving, leather working, basketry, manufacture of wooden toys, wood carving, simple metal working.

6. *Hospital Service.*—A certain proportion of patients are judged by their ward surgeons to be able to perform various necessary duties about the hospital, such as sweeping floors, helping in the kitchen, etc. Work of this sort has been assigned on prescription and recorded as a part of the reconstruction

program. When properly supervised it can be readily fitted into a scheme of graduated exercise.

7. *Military Drill.*—While the war was still in progress and the effort to return men to military service was still strong, a "Reconstruction Detachment" was organized at No. 16 into which were brought all men approaching recovery and destined soon to be returned to duty. Such men were given daily military drills, were present at retreat, etc. This routine was continued in a slightly modified form after the signing of the armistice.

8. *Graduated Walks.*—At some of the tuberculosis hospitals, notably at No. 8, extended use was made of graduated walks as a part of the reconstruction program. To a less extent this feature was developed at No. 16.

9. *Recreation.*—Athletic games are capable of contributing very largely to the restoration of physical function in cases where ordinary muscular functions are impaired. Thus in orthopedic hospitals the extensive development of athletic sports was natural. Such forms of recreation may also assist materially in keeping up morale. In the treatment of tuberculosis, however, active games have to be prohibited; but mild

A CITIZENSHIP CLASS. These alien soldiers all received their naturalization papers.

inactive diversions and games upon the wards are encouraged as a morale measure. For reasons of morale also the Reconstruction Service cooperated at all times with the various welfare agencies in a general provision of recreation for the post.

10. *Social Service.*—On March 6, 1919, the Surgeon General's Office sent to this hospital a special reconstruction aide designated for "medical social service." The field of her operations was most problematic, but the incumbent proved to be a well-trained and tactful woman who made herself distinctly useful in many ways. In general her duties were to collect personal histories of all patients as required on the Surgeon General's Office Form 58, to put patients in touch with the facilities of the Reconstruction Service, to see that every case of need of every sort was passed to the appropriate official or welfare agency, to follow each patient through the hospital and to see that his case was cleared up at all points when he left.

Criticism of Results

Having outlined the purpose of the reconstruction work and the methods adopted for reaching those objectives, it is now possible to make an appraisal of results.

1. *Return of Men to Military Duty.*—The work had not gone far enough prior to the signing of the armistice to have given definite results in the return of many tuberculous men to military service. It is obvious that such returns would necessarily be slow and comparatively few, and that the majority of the men returned would be fit only for limited service. Yet there was considerable promise of results within these limits.

2. *Vocational re-education*, as has already been pointed out, has proved to be generally impracticable under hospital conditions, and the burden of this responsibility has been taken over by the Federal Board for Vocational Education. Experience seems to indicate that a few cases in civil sanitoria may be found where a change of occupation seems advisable and in which the beginnings of vocational retraining can be made during the sanitarium period. Inasmuch as the cure of tuberculosis frequently involves the adoption of an entirely new plan of life, with all its psychological readjustments, and since vocation must bulk large in the adjustment of most men, it is obviously desirable to meet these problems as a part of the treatment and during the period of sanitarium reconstruction.

3. *Graduated Exercise.*—Avoiding still any argument as to the therapeutic value of graduated exercise, the possibilities of auto-intoxication, and all that endless debate, we may reiterate the statement that such exercise is perfectly feasible as a part

of the reconstruction program. However if it is to have any practical application it must have much more constant medical supervision than could be given to it in any of the military hospitals. This supervision must gauge the whole daily sum of exercise for each patient, not merely the relatively light work of an hour in the garden. This criticism plainly applies with equal force to the prescription of graduated walks. Such regular walking exercises may possibly be of considerable value to tuberculosis patients, but not unless they are supervised with great care.

4. *General Education.*—The general teaching given in the reconstruction schools was apparently of much practical value. Indeed it is clear that more of this work should have been done. Many patients who sorely needed help missed the opportunity. Possibly more compulsion or greater tact in handling these patients would have accomplished more. The work was most needed in the most elementary subjects; but much more might have been done to the general profit in commercial subjects, particularly typewriting and simple bookkeeping. The work succeeded best when given to small groups or to individuals upon the ward porches.

5. *Americanization.*—The work for the Americanization of alien soldiers has been one of the most fascinating and inspiring undertakings in the whole reconstruction enterprise. Its value can not be doubted. It has met with distinct success. While it has been peculiarly appropriate to the Army, it has such a general social value that it may seem almost indispensable in future tuberculosis work. Tuberculosis in our country is likely to be always partly a problem of the foreign population, of un-Americanized, uneducated, ill-paid social groups; so that whatever may be done to assist in general education and in Americanization cuts toward the very root of the disease.

6. *Handcrafts.*—The striking success of the handcrafts in all the tuberculosis hospitals makes it necessary to consider this branch of the work with some detail. First of all it must be seen that the success of the work was due in considerable part to the personal attractions of the reconstruction aides. This is offered as a cool scientific statement without any implications. The women secured for this service during the war period were nothing less than remarkable in their high character, their wholesome behavior and their inspiring personality. In this work personality counts very heavily.

But the character of the work itself makes it highly effectual to the purposes in view. It is interesting; it occupies the hands

and mind; it is not tiring; it can be taken up or laid aside at will; periods of work alternate pleasantly with periods of relaxation; the finished product has demonstrable value. It must be recognized as a fact that the great majority of patients are not capable of any intense of prolonged mental attention. The handcrafts, however, reach their minds through their fingers, the shortest and surest route.

The educational value of these crafts has not been sufficiently recognized. Education is too generally regarded as a wholly mental process. This is far from true, yet if it were the literal fact, the handcrafts might still be the most effective means of arousing mental activity. Work upon a bead-loom, for example, requires a certain concentration of attention, and control of attention is one of the foundations of all education. It requires further a close coordination of the eye, of delicate muscular movement and of mental direction. This cooperation of mind and body is in itself education in one of its highest and best forms.

Moreover the pupil in handcrafts learns something of design and of honest construction. Both these items are of serious value to every hand worker whether he be carpenter, tinsmith, weaver, tool-maker, or farmer. It is a great defect of modern society that it depends too much on machinery. Everything we touch is machine-made. The common laborer in particular hardly ever sees or touches anything but machine-made objects. He begins life in a machine-made go-cart, eats canned food from a machine-made table with a stamped steel knife, fork and spoon, dies in the hospital in a machine-made bed, is buried in a machine-made coffin and marked with a machine-made tombstone. When such a man once makes with his own hands a good basket or leather pocketbook he begins to realize the value of honest craftsmanship—the place of personal responsibility in the day's labor. This is a most fundamental element in human psychology now largely lost in a mechanical world where objects are made by machines, not by men. The men only feed the machines and are themselves controlled by another social machine called a labor union.

Still further, though less important, it must be pointed out that the objects made by the patients taking handcrafts have an immediate commercial value. They are readily saleable and at good prices. The objection sometimes raised against the work of tuberculosis patients was conspicuously absent from our experience at No. 16. The patient who turns out a product which sells for real money experiences a stiffening of morale which is

of the utmost value. No matter how discouraged he may have been he can no longer feel himself completely down and out.

This feature of the work, the sale of products of occupational therapy, demands careful handling, but it is worth all the trouble required.

7. *Hospital Service.*—Experience at Hospital No. 16, supported by the experience of others, shows that hospital service is a very difficult form of exercise to administer. The difficulties in fact are so great as to make the effort inexpedient except in a minority of cases. It seems probable that in civil hospitals where simpler relations obtain amongst patients and personnel more can be expected. Especially if a cash value can be placed on the service of the patient and this amount subtracted from fees which the patient must pay, or some other arrangement can be made so that he feels he is being fairly remunerated for his work, reasonably good results may be expected. This form of reconstruction work, however, is the most difficult of all to manage and the least effective for all purposes, so that we can hardly feel that those sanitaria which have made it the leading feature of their reconstruction programs have fairly broached the possibilities in this field.

8. *Recreation.*—While athletic sports are hardly admissible to a program of tuberculosis therapy, other forms of recreation are highly desirable. In every hospital, sanitarium or convalescent colony adequate provision should be made of wholesome recreative recreation. This matter is of such importance that it must not be left to chance. The recreation should be planned, directed, carefully supervised and coordinated with all the other therapeutic measures which we are grouping here under the rather loose general term of reconstruction. In the military hospitals these recreation activities have been divided amongst several volunteer welfare organizations, an arrangement obviously impracticable under other circumstances.

9. *Welfare Work.*—Inevitably a certain amount of welfare work or social service was done by the Reconstruction Service at No. 16. The more definite undertakings of this sort were made at the hands of the medical social service aide sent from Washington for that purpose. The great bulk of all such work however was done by the Red Cross, the Y. M. C. A., and the K. of C., not forgetting the official chaplains. A most considerable amount of such work has to be done at every civil hospital. Our experience shows that it can be effectively administered as a part of the reconstruction program and indicates pretty definitely that this is the best way in which to direct it.

Summary of Results

This experiment in the application of reconstruction ideas to the tuberculosis hospitals of the military group covered something over one year. During that time great changes occurred, not only in external conditions but in our intellectual conceptions of the purposes and methods. These changes have followed one another with bewildering rapidity. There was no leisure for study, reflection and generalization. These experiences remain yet largely undigested. There are many observations which still seem to contradict one another. Under such circumstances any statement of conclusions must be offered with great care. However a few points seem to be sufficiently clear to bear statement.

1. The reconstruction program has definite value in the tuberculosis hospitals. Every one seems to agree to that. Its chief utility lies in the assistance which it gives to the rest cure and the favorable mental attitude which it induces in the patient.

2. The work done in lines of general education and Americanization has also had considerable value.

3. The most successful feature of the program has been the occupational therapy or crafts work on the wards.

4. To make the work as successful as it should be, strict medical supervision is necessary. As a matter of administration, however, this supervision may be largely delegated to reconstruction officers as was done at General Hospital No. 8.

5. The experiment has been valuable, has probably been worth its cost, and much of the experience gained can be passed along to civil institutions.

The Future

Indeed this look into the future is what chiefly justifies the whole experiment. Tuberculosis we have always with us, and the war against it promises to be a much longer affair than the little flurry with the Central Powers. The treatment of tuberculosis in sanitoria and colonies of various sorts seems likely to be increasingly important, and in all such circumstances some form of reconstruction ought to be utilized. What does the Army experiment suggest for adoption into the peace-time warfare against tuberculosis?

1. In any given institution the work ought to begin on a small scale and be allowed to grow as its value is demonstrated and as means are available.

2. In a great majority of cases this beginning can best be

made with one first-class reconstruction aide, who must be a woman of experience, sound character and attractive personality.

3. Other sides, male and female, may be added as circumstances warrant. A male director should be appointed whenever the extent of the work justifies, and this director should be an educator rather than a physician. This distinction is important.

4. From the beginning there should be combined in this one service all the reconstruction functions of the hospital, *i. e.*, all social service, teaching, direction of crafts, supervision of recreation, etc., including everything now known either as reconstruction or welfare work.

5. In general the work should begin in the wards, and only after there are positive advantages in sight should there be developed any separate workshops or schools. Exception may be made for schools maintained primarily for the protection and observation of children of tuberculous parentage.

6. Hospital service as a form of reconstruction must be handled with great care, and should be presented in such a light as to seem to offer a direct financial advantage to the patient.

7. Gardening, poultry culture, bee-keeping and other light forms of agriculture may be used where good physical equipment and good teachers are available, but the medical supervision must be exceptionally careful.

8. The work must be at all times under the full control of the medical service, but best results may be expected if the details of all reconstruction activities are left entirely to the reconstruction workers. The value of experienced educational workers in this field seems to be fairly demonstrated.

9. Arrangements should be made in most hospitals for selling the products made by patients. These arrangements are important; they may also be difficult, and they should therefore be managed with considerable prudence.

THE COST

Every one who considers the introduction of reconstruction work into civil sanitaria must early face the question of cost.

To begin the work as recommended with one first class woman aide will cost approximately $1,500 a year for her salary. There should be a fund of about $500 for initial equipment. In the judgment of the writer it will be entirely feasible in most institutions to make the products of occupational therapy pay the cost of raw materials, probably something over, so that steady expenditures on this account need not be anticipated.

It may be estimated that each good reconstruction worker can care for from 50 to 100 patients. Indeed one single worker could do a world of good amongst 500 patients, but a ratio of 1:50 or 1:100 is safer.

If workshops or outdoor schools or other buildings must be provided they present another item of expense, but this item is so variable as to escape estimate.

Post-Sanitarium Applications

The spirit and methods of reconstruction furthermore seem capable of projection even beyond the sanitarium in the treatment of tuberculosis. It is well known among tuberculosis workers that one of the most critical periods in the cure comes at the point of discharge from the sanitarium. The patient passes abruptly from a regimen of rest (or comparative rest) to a full day's work, from the wholesome surroundings of the sanitarium to the old home, sometimes unsanitary to a degree, from constant medical supervision to no supervision at all. Worst of all he feels compelled to do what others do, whether that be hard lifting in the day's work or staying out late at a dance. The results are seen in a deplorable percentage of relapses.

It has seemed that much might be gained if this transition could be made more gradual. The one crucial point usually lies in light part-time work at which the patient can become partially self-supporting and in which he can progress safely to heavier labor and longer hours as he gains in strength. In short the problem is one of graduated exercises, of occupational readjustments, and follows logically upon the reconstruction work of the sanitarium period.

The solution which appeals to many minds as promising for trial lies in the provision of industrial colonies, institutions which would lie between the sanitarium and general industrial life. A very interesting study of this proposition has been published recently by Dr. H. A. Pattinson.[2] The present writer prepared an outline project running along similar lines which was considerably discussed at General Hospital No. 16 by the medical and reconstruction staffs. The outline is herewith reproduced as suggesting a further extension of reconstruction ideas to the everlasting fight against tuberculosis in civil life.

Reconstruction Town

Sketch Project for a Village devoted to the Care and Rehabilitation of Persons recovering from Tuberculosis

[2] Federal Board Vocational Education Bulletin, Series 6, No. 32, June, 1919.

1. *Purpose.*—Primarily to supply post-sanitarium care for persons recovering from tuberculosis, and to effect their full and permanent rehabilitation, physical, economic and social.

2. *General Scheme.*—To provide the facilities necessary to this purpose in a special village or villages. Preferably such centers will be created *de novo* in selected locations. The essential facilities would appear to be:

(*a*) A rather full and paternalistic control of industries, exercised perhaps by a director of industries.

(*b*) Adequate medical supervision, probably exercised through a public dispensary and clinic.

(*c*) An intelligent social service.

3. *Physical Setting.*—Such a colony should be located within reasonable distance of large centers of population yet outside the urban districts. The village should be designed by the best specialists in modern town-planning and industrial housing, and such plans should conform clearly to the special purposes to be served.

4. *Location.*—Sites for such colonies might be found within or upon the borders of the national and state forests. Certain advantages would derive from such location, in particular the following:

(*a*) Large tracts of suitable land are easily available.

(*b*) The surroundings would be wholesome, sanitary and attractive.

(*c*) The forests supply the foundation for permanent industries especially adapted to the needs of such a colony. This is a most important consideration.

(*d*) Necessary conditions of land tenure and administration would assist toward the somewhat paternalistic control essential to success.

5. *The Family Unit.*—Since this plan assumes the protracted—in many cases permanent—residence of convalescents, it must provide for their families. In fact an essential feature of the service contemplated is to transplant infected families to a new environment where the children may be protected.

6. *Economic Foundation.*—Industries should be of such a nature and managed in such a way as to provide graduated labor, under safe and wholesome conditions, to convalescents and recovered patients in all stages. Light occupational therapy could be given to chair patients or those still in their homes; light work in special shops for short periods to patients more fully recovered; full-time work to those capable of it. All would be under constant medical inspection. (The small wood-work-

ing industries seem particularly adapted to this end.) Obviously these industries must be organized and supervised with a view to the rehabilitation of men and women rather than to the exploitation of man power or of the forests.

7. *Other Employments.*—The economic ideal would be found in a completely autonomous and self-supporting community. Beside the basic industries there would be many correlative functions open to convalescents and to recovered persons. These would include laundry, garage, telegraph and telephone service, shop-keeping, road mending, etc. In particular should opportunity be available for small farming, truck growing, poultry keeping and other food-producing enterprises as a part of the community development.

8. *Social Engineering.*—It would be clearly necessary to provide schools, religious opportunities and specialized facilities for recreation. These should be directed by competent persons and definitely coordinated with the therapeutic and prophylactic control.

9. *Financial Support.*—Such a community might eventually become largely self-supporting. At its inception, however, considerable sums of money would be required. It would probably be necessary to look to private sources for these funds rather than to federal or state support.

10. *General Control.*—Might be exercised through a special board of trustees, through the National Tuberculosis Association, or in some similar way. Some form of self-government for the community should be devised compatible with the central control of essential features.

ACADEMIC UNREST AND COLLEGE CONTROL

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GREAT unrest exists, for many reasons, in academic circles, but the most disturbing protests are against efforts to control expression of opinion by college professors, which are denounced as not merely infringements upon the right of free speech, but also as attacks upon "academic freedom," certain to bring about disaster in the near future. The general unrest may be regarded by some persons as manifestations of the growing unwillingness to endure restraint of any kind; yet one must not dismiss it as simply a phase of the anarchistic tendency in all classes of society; the matter is of vital importance; it involves complex problems, affecting the usefulness of our colleges and secondary schools.

A man, sole occupant of a far-off island, is untrammeled save by physical conditions; but in a community no such freedom can exist. Each man has rights, but, in exercising them, he must not interfere with the rights of other men. This law is recognized as obligatory especially upon men in responsible positions, who, in the nature of the case, may not do many things, which an ordinary citizen may do. They have consented to curtailment of freedom because they prefer honor or emolument. When a man becomes employee of any type, be he bank president or sorter of rags on a dump, he voluntarily deprives himself of rights that he may gain something more to be desired. This is equally true of professional men, since they, in some sense, are employees. They make the surrender without compulsion; no man is compelled to become clergyman, physician, teacher or lawyer. He is untrammeled in choice; the world is wide and he may gain a livelihood in any one of many directions.

But there have always been college teachers who refuse to concede that they have renounced the exercise of any personal rights; men, whose acts assert the conviction that a college appointment confers the right to be a free lance in discussions relating to morals, social matters, politics or religion. Yet no one has suggested that such appointment endows a man with omniscience or even with ordinary common sense. But col-

leges are under bonds, which must be kept in mind not only by the trustees, but also by all employees, from the president, down or up. Gifts, usually more or less conditional, have been received from donors and similar gifts are sought from others. The greater part of the older colleges were founded as denominational schools or in close relations with a group of religious bodies. The usefulness of a college is dependent on the goodwill and confidence of the community, which is apt to be conservative in educational matters—for, however radical in opinion the ordinarily intelligent man may be, he rarely desires to have his children begin where he expects to end. As holders of trust funds and as responsible for training of youth, trustees of colleges are under obligations, which honorable men can not ignore—and those who seek appointment as college teachers should bear this in mind. Reference to such permanent obligations seems to give pain to some advocates of "academic freedom," as savoring of vulgar "commercialism" and as unworthy of consideration by dwellers in an intellectual atmosphere. But commonplace honesty ought to be at least as important in the conduct of college affairs as in ordinary life.

"Independent thinking" does not mean advance or originality in thought; it may be only erratic thinking. Opposition to prevailing opinions is no proof that the man is a "reformer"; his sincerity in independent thinking has nothing to do with the matter. He may be convinced that marriage is merely a survival of property rights; that a trade unionist, punished for dynamiting houses and imperiling lives, is a martyr in behalf of human rights; that ownership of land is positive proof of crime in the past or present; that the whole organization of society is based on injustice by the few; that the only hope for this world is overthrow of all conditions now regarded as normal; but this sincerity gives him no right to demand that the college retain him and pay a salary that he may conduct a propaganda, at its expense, inside or outside of the classroom.

But there are matters which too rarely are considered carefully. Colleges do not exist in order to petrify intellectual conditions, or to prevent increase of knowledge; no sane man would maintain that restrictions should be placed on investigation, for such procedure would be disastrous. A teacher, who is not a genuine investigator, becomes a mere lesson-hearer, a purveyor of second-hand opinions, as expressed in the text-book. To be efficient in the classroom, one must be a coherent thinker; but that mode of thinking becomes confirmed only after patient search for the truth, diligent comparison of arguments on both

sides of the questions involved. This type of work should be done without consideration of possible results, as truth alone is the object sought. When the writer entered college, more than sixty years ago, the respectable community knew that scientific man and infidel were practically synonymous terms—astronomers alone being possible exceptions. But chemists, physicists, geologists and naturalists held close to their work; their discoveries came in quick succession and, in great part, were accepted as genuine. The world soon recognized that the prevalent conception respecting scientific men was born not of knowledge, but of prejudice, that it was merely an echo of the metaphysicist's dictum, that study of material things unfits a man for contemplation of spiritual things. This was the outcome of untiring, patient investigation, of which the results were published, with rare exceptions, in a judicial manner, without reference to misrepresentation by opponents. Such work must be encouraged not only in natural science, but also along other lines of study. There are problems in psychology, economics and sociology, which are perplexing to the last degree, as the facts are obtainable only with difficulty and the evidence is apparently conflicting. Here, however, the temptation to publish incomplete work is too great for men anxious for recognition by the reading part of the community. Startling hypotheses are apt to be published as if they were final results. Such hasty publication should be discouraged as emphatically as patient, judicial investigation should be encouraged. To determine the border line between investigation and mere compilation of so-called statistical facts is difficult—it is not easy to determine when veal becomes beef; but there must be a determining body.

Equally perplexing are questions relating to participation in political and religious discussions. The opinions now maintained by the writer are wholly different from those which he maintained twenty-five years ago, the change being due as much to actual experience as to wide observation. It is not wise for college professors to take active part in such discussions; their calling unfits them.

In the class room, they are regarded by students as practically infallible and, in time, they are apt to become convinced that the students are correct in their estimate. Too often the nature of their studies renders them self-centered and, except in a few departments, they are not brought into such contact with the business world as could satisfy them that they are not a superior race. This positiveness is only too manifest in the

cases where intellectual force or the exigencies of conflicting elements have put them into prominent places, for there they exhibit a strange indifference to public opinion. It would be well if professors abstained from active participation in public affairs and devoted their energies to work in their special departments. But such limitations should apply equally to all members of the staff; the president should not be permitted to be Oliver Twist for one political party, unless a professor be permitted to be the Oliver Twist for an opposing party, if he so desire. The chief objection to prominence of this kind is that it is due to the prestige of the college and in very small part to the man's ability. The respectability of the college is capitalized to cover defects of the machine-managers. Usually, the innate sense of propriety determines well the extent to which one may go, but, certainly, there have been, as there will be, occasions when college authorities must decide whether or not they will permit expenditure of college funds to aid a man's efforts to gain prominence in church or in state.

It is well to note the strange tendency to ignore the fact that, speaking legally, all persons receiving salary from a corporation are employees. This assertion has been resented bitterly by some writers, who hold that college teachers are appointees, not employees, and that the corporation, having confirmed an appointment, has no authority to remove the appointee. If such were the condition, the college trustees would do well to seek the heirs of donors and to return the gifts, as the trusts can not be fulfilled. But the claim is without basis. The argument that the President of the United States appoints justices of the Supreme Court but can not remove them is not accurate. The President nominates, but the Senate confirms or rejects. The Senate is the appointing authority, and it is the jury before which an impeached judge is tried. Similarly in a college, a committee or the president nominates candidates, but the trustees appoint or reject. No other condition is possible, as financial agreements must be made.

A notion seems to prevail among teachers that peculiar sacredness is attached to their profession. This perhaps is of medieval origin, for in most of Europe, teaching was one of the many duties required of clericals. In this country, the older colleges began as preparatory schools for the Christian ministry and were in charge of ministers. Perhaps, the wretched salaries paid to clergymen and college teachers are due to medieval conceptions, for clericals in the dominant church were celibates, supposed to need little of this world's comfort. But

there is nothing sacred about the profession of college teaching; no reason exists why an "appointment" should be so guarded as to render extremely difficult the removal of an incompetent or indifferent teacher. Professorships should not be havens of rest for the slothful or negligent. In other professions men must prove themselves competent or must fail.

While recognizing the right and the duty of trustees to remove slothful, incompetent or injurious professors, one must insist that there are cogent reasons why a certain degree of security must be assured to the professor; and these have been conceded in the better grade of colleges, so that one receiving a final appointment has a, so to say, civil service hold upon the position. Preparation is long and costly; the salary, at best, is meager; promotion is very slow; while a man's efficiency should increase as he grows older in the work. The honest worker must feel that, as long as he does his work faithfully, his position will be secure. The interests of colleges demand this security because the teaching staff is the essential portion; its members have been chosen to do the work for which the college exists. There have been comparatively few cases in which abrupt or unjust "removal for cause" has occurred, but, unfortunately, they are not unknown. Trustees are almost isolated from individual professors in our larger institutions and are liable to be influenced by opinions of an officer who, honest perhaps, is certainly human, and is not apt to love those who do not see eye to eye with him in matters of policy. Unquestionably, some recent events have led thoughtful men to feel that radical changes must be made, if proper working conditions are to continue.

The American college is a legal body authorized to conduct an educational work without pecuniary profit to the incorporators. The trustees are not expected to manage details of that work, though they are responsible for them as much as for the financial details. The corporation employs a number of supposedly qualified persons to care directly for the teaching, one being designated president. The college thus consists of trustees the faculty, with the students, who are raw material to be fashioned into finished product. A university differs from a college only in that it consists of several schools, each with its own faculty. All machinery necessary to effective working appears to be provided in this organization, but, naturally, some adjustments have to be made in most cases to secure smooth operation.

Originally, the trustees were intended to act as "nursing

fathers," guarding the orthodoxy of the professors, who were dependent on the fees for salary; if any deficit came, the faculty had to look after it. As a rule the trustees had great respect for the professors and cultivated their acquaintance assiduously. In later years, the great increase in property and the greater broadening in scope of work, with consequent enlargement of faculties, have made it almost impossible to maintain the intimacy formerly existing between trustees and professors; one is justified in saying that in some of the larger universities, there are trustees who can not tell the names of the oldest professors in the several faculties. No work can be conducted properly amid such conditions—a close personal bond must exist between trustees and professors. The faculty should have general control of educational affairs and the trustees should have general control of financial affairs. But there is a borderland where the duties overlap; it is necessary that the trustees consent to changes in curriculum and methods and, at times, the faculty must be consulted in reference to expenditures and buildings.

The president is supposed to be a bond, as he is usually a trustee; but, unfortunately, instead of bridging the gap, he is apt to convert it into a wide chasm, over which he may fly in a private aeroplane. Action by trustees has placed in his hands control of many matters, which should be delegated by them to no one. The self-perpetuating character of the board, so generally existing, makes possible for a shrewd man to fill vacancies with persons of his own choosing. In far too many instances, the president was not selected because of fitness to have oversight of the educational work; he is no bond between trustees and faculties and, under present conditions, he can not become one; everything tends to make him autocratic, as though the college were his personal property.

Each faculty in a university should be represented on the board of trustees by its dean, *ex officio* and without vote. This officer should not be selected by the trustees, but should be elected by the faculty in secret ballot, that he may be truly representative. This, however, is not sufficient, a closer bond is essential. A joint committee of trustees and professors should be chosen by each board for each school, two trustees and two professors, with the president as chairman, *ex officio*. All matters affecting any school should be referred to its committee, and no action should be taken by the trustees until after a report from the committee has been presented. Such an arrangement would bring trustees and professors into definite

relations, would prevent the former from becoming nominal and would increase the dignity of the office. Such committees exist in some universities, but they are not what they should be as, in most cases, the members are selected by the trustees, the faculty having no voice in the appointments.

These propositions are based on the assumption that trustees, president and professors are well qualified for their respective positions. Unfortunately, this assumption is not wholly correct. Reformation in college affairs must be begun by complete change in method of selecting men for appointment to the several offices. The writer desires to offer some suggestions.

The board of trustees is responsible not only for the financial affairs, but also for the teaching work, the latter being the business for which the corporation was formed. This combination of responsibilities calls for strong men, whose hearts are in the work. One might well imagine that a liberal proportion of professors should be in the board, as they understand the nature of the work, while their success in rearing families on small salaries proves no slight ability in finance. The writer knows of more than one instance, where a university was saved by the faculty, after a board of able lawyers, clergymen and business men had given up the attempt in despair. But this type of representation has never been tried in the United States, though it has been remarkably successful in Scotland. In this country the office of college trustee seems to be regarded generally as a post of honor not of responsibility. There may be no personal responsibility before the law, but for that reason the moral responsibility is greater. Eminence in professional life or success in business affairs is no evidence, in itself, of fitness; no more is possession of wealth or a reputation for generosity. Men chosen to trusteeship should be familiar with the nature and needs of college work and they should have time as well as will to serve the institution. No man with proper self-respect would consent to be a nominal trustee; he would not endeavor to shirk responsibility by transferring his duties to a president. Any trustee who has not time and inclination to do hard work should resign, that a proper man may have the place.

The office of college president, anomalous in many ways, was an outgrowth of rapid expansion after the Civil War. In earlier times, the president was the mouthpiece of the faculty, over which he presided. Now, however, he is the executive officer of the corporation, general manager of all operations, financial or otherwise and in many cases he is member of the

trustees. The crying need of every college is money and more money for "expansion" and for buildings; and the president is expected to find this money, as well as to advertise the college, so that the number of students may be increased and the need for still more money may be emphasized. The condition is bad; the duties are unrelated and should not be assigned to one man. The college or university president should be concerned chiefly with educational affairs, an *ex officio* member of each faculty and a genuine bond between them all. He should be chosen because of proved fitness to superintend the general internal affairs of a college; because of known probity in speech and action; and he should be a teacher earnestly in sympathy with the teacher and his work. Happily, there have been, as there are still, some presidents of this type, who care less for "expansion" than for honest work. Securing of money should be the task of a special officer.

Trustees and their duties are important, but professors and their duties are more important. If the faculty be incompetent, the college can not do the work for which it was founded, even though the lists of students increase greatly. No shoe factory could claim public respect and confidence if it merely succeed in foisting on the community a great quantity of inferior shoes, labeled as the best. The type of output is the test; if it is to be good, the workmen must be good and honest.

To secure proper men the college positions must be inviting; but they are not inviting to strong men. There is little pecuniary inducement; a life of leanness is the prospect. Formerly there were inducements for men who cared less for money than for opportunity to devote their lives to research. For such men, the long vacation and the few hours of teaching were all-important. But vacation and "literary leisure" no longer exist for the younger men in our great universities or for the greater proportion of the older men in the others. Summer schools increase the total roll of students and the fees received by teachers help to meet payments for the necessaries of life. "Expansion" of course and multiplication of schools without multiplication of professors have increased the hours of teaching. Even in many of the larger institutions the hours of work are scattered throughout the day; too often, the intervening hours are occupied in committee work, for the machinery has become complicated. Vitality is sapped and little energy or will-power remains for genuine study. If a man persist in research, his associates may soon have opportunity to lament the untimely end of a promising investigator. Certainly, the

old-time inducements no longer exist, and it is becoming increasingly difficult to secure able, ambitious young men as teachers. If present conditions continue, our colleges will soon cease to be nurseries of science and literature.

The board of trustees ought not to choose men to serve as professors; ordinarily, its members are not familiar with the requirements and know little about the duties which a teacher must perform. Under present conditions, the president of a college or university should not be authorized to make selections or to present nominations. He has no time to investigate the claims of candidates and, in too many cases, he is not competent. No one would suggest that he select professors in law, medicine or finance, yet he is thought competent to choose college professors in arts and science, because he had taken a college course somewhere and perhaps had taught during a year or two in a secondary school, to secure means for a course in a professional school. His ideal of college work and his conception of successful work frequently differ greatly from those of the genuine teacher.

The primary selection of candidates should be made by a committee of professors in allied departments, aided, if possible, by competent men outside of the college. This committee should select two candidates to be recommended to the joint committee on the school concerned, by which a special investigation should be made and a choice made for nomination and confirmation by the board of trustees. A complicated process, one may say, but an ounce of prevention is better than a pound of cure, even in college circles. It is all-important to avoid saddling a college with hasty injudicious or not just men. A modification would be necessary in selection of assistants and instructors, but in no case should the decision be left to the caprice of one man.

The suggestions are: close contact of trustees and professors is essential; where several schools exist, an intimate bond should unite the faculties; trustees and professors should be selected most carefully; the work in each department should be supervised and all should know that a college is not an asylum for the indifferent, incompetent or slothful; a just salary should be paid and the importance of opportunity for study should be recognized; zeal for increased number of students should be discouraged and quality, not quantity, of the output should be the aim.

PHILOSOPHY IN THE SERVICE OF SCIENCE

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PHILOSOPHY is often charged with being careless of science or even with being deliberately superior to science and anything scientific. Among scientists the very word philosophy may even be a word of offense. In the name of all that is right and true and lovely and of good report the devotee of science is warned that above all things he must not get philosophical. To quote the Scriptures—somewhat at a distance—he can not serve science and philosophy. Simply, philosophy is unscientific.

As to this charge Lord Byron has happened to speak wisely:[1]

> And after all what is a lie? 'T is but
> The truth in masquerade; and I defy
> Historians, heroes, lawyers, priests to put
> A fact without some leaven of a lie.

Philosophy is indeed unscientific; but also philosophy has long and faithfully been in the service of science. How long? Ever since science began. How faithfully? Let me not say, lest I seem to boast. Only, in a word as quaint as appropriate, philosophy has been true handmaid of science, serving her mistress well if not always apparently. Philosophy most certainly, being so loyal a servant, would not speak rudely or disrespectfully; but many another faithful maid has said of her mistress: "I just tell you, it 's me as has taught her how!" Philosophy's service of science, then, has not been exactly slavish or conventional; but it has been real and, as does happen even in service, it has been instructive.

Of course philosophy has served other disciplines besides science; theology, for example, as will be pointed out here in due time; but its service as handmaid of science, besides coming in an interesting historical sequence after that of theology, obviously relates to the subject of this present essay. Also, as it is finding expression at the present time, especially if the present be appreciated in the light of the historical approach, it has special significance for certain tendencies of the time. In her service of science, furthermore, philosophy proves every

[1] Don Juan, Canto xi, stanza 37.

century or two to have changed her mistress, leaving one science to go to another. Her fickleness, however, like her unconventional way, in no sense detracts from the interest and importance of the relationship. On the contrary, when understood, it throws light on the real nature and value of the service itself and also it provides any one, who can and will read it, a most absorbing story.

Now I can not set up any claim to being a good story-teller; but I shall make an attempt, trusting that my own interest will supply some inspiration. Before beginning, however, it seems wise that I say something of the general character of philosophy's service of any discipline. Thus this service is—how shall I put it?—wholly characteristic, of course; I suppose, like that of any handmaid with her own inevitable manner, brogue, accent, atmosphere. Being what she is, philosophy, however servile, must always be concerned, whether quietly or assertively, with the universe, not just with some special field or point of view. Generalization is her very life and purpose and, although it may be what makes her restless and unconventional, it is her opportunity for a vital service. True, the opportunity has great dangers and from these many have suffered; but opportunity always implies danger. Philosophy, again, must be speculative, even in a sense imaginative, inexact, poetic, not soberly literal, not formally dogmatic, as we say of theology, or empirical and positive, as we say of exact or would-be exact science. Her interest, too, must be vital and appreciative, not just "objective," not just descriptive and explanatory, not under constraint of too precise instruments and too accurate measurements; concerned, then, with values, not merely with facts. So the commands, the specific doctrines and precepts of her mistress, whoever this happen to be at the time, she takes and must take only as mediating symbols or—a better word—analogies in the sense even of metaphors. Especially must philosophy never commit the error, by no means uncommon among scientists, of actually or virtually taking useful standpoints and methods as literal indications of reality. No science is metaphysics. So true are the various things that have just been said that philosophy's service of a science is often transforming or transfiguring almost if not quite to the point of baffling recognition. Once upon a time, you know, just an ordinary maid went out in her mistress's clothes; was met on the street by the mistress herself, and was not discovered. Philosophy, while no ordinary maid, must still take liberties. Philosophically thinking the whole after the manner of any scientific part, be this doctrine, standpoint or

method, may or indeed must lead to some violence. Facts and methods, valued for philosophy as for life, must undergo change. It is, after all, a poor service that does not make itself really felt!

But, to turn now to the story, the progress of Christendom does show philosophy in a most significant succession of positions of service. To begin with, as often chronicled, in the Middle Ages philosophy was handmaid of the Church or of dogmatic theology, *ancilla ecclesiæ*. In the seventeenth century or thereabouts began the service of science; first, during the seventeenth and eighteenth centuries, of mechanics and mathematics; then, in the nineteenth, of biology; and, more recently, of anthropology and psychology. Theologism, mathematicalism or mechanicalism, biologism and psychologism: in such terms, very general indeed, may one tell the history of the philosophy of Christendom.

And this history, as it is true, can not but have interest. Thus, it implies what many a scientist would readily and too cheerfully overlook, that theology has a real place in the growth of the intellectual life, being even a cry in the wilderness before the coming of science, and that each of those sciences, at least for philosophy, has or has had its own special day and generation. It is true that for those who must regard science and theology as essentially opposed and incongruous any suggestion of historical sequence and continuity is bound to cause at least wonder, if not something stronger! Many, too, may wish to protest against a view that arranges important sciences in a temporal order and so seems to question their equality and their essential contemporaneousness. No science cares in these days to be treated as a "has-been." But, whatever the wonder or the protest, theology has had its real place and, although herein is no ground for denial of contemporaneousness, the different sciences do fall into an historical order; the earlier, as I would submit, being now in varying degrees of only mediate interest and value, the latest of immediate interest and value, to life and philosophy.

Furthermore, philosophy being life's reaction, intellectual and volitional, to the world as experienced and as immediately interesting at any given time, in our history with its sequence: theologism, mechanicalism and the rest, we can see that upon each change in the ism man is less aloof from the natural world, more at home in this world, more intimate with its life. In short—and just here is a matter of special interest—that sequence reveals a centuries-long process of civilization—syn-

onymous with naturalization?—or say biologically of adaptation to environment. If the phrase, adaptation to environment, be misleading or out of date in its point of view, then any one who prefers may substitute sympathetic or functional change in man and his world or, again, progressive variation in their manner of interaction or in the mediation of their essential and persistent relationship. In history as in biology, unless I be very much mistaken, organism and environment have evolved or grown together. Still, for simplicity's sake, we may here keep the admittedly one-sided point of view of the more conventional phrase, adaptation to environment.

After a fashion every one knows how our western civilization, how Christendom, at first shut up in an unworldly—at least in theory and proclamation unworldly—institution, gradually came to earth; at first with much reserve and fear, with little real candor, but eventually with open enthusiasm and appreciation. In the twelfth to sixteenth century, notably in the period of the Renaissance, the great institution, the Europe-ruling Roman Catholic Church, turned creatively artistic, seeking so to humanize and acclimatize or naturalize all the various factors and practises, the ways and the offices, the doctrines and the imagery, of its life and organization. However selfishly and defensively, it made real appeal from the spiritual to the sensuous and physical, from its own separate world to the "external" material world, from the unnatural or supernatural to the natural, evincing an interest in rhetoric as well as in dogma and logic, in man's sensitively living body as well as in his immortal soul, in the vernacular languages as well as in the dead and other-worldly Latin and at least for first resort in the subtleties of cunning and artful diplomacy in place of compulsion by holy mandate or—the worldly counterpart of this—brute force; and, while the Church turning thus to an artistic expression of its life doubtless did have at first more of intrigue and indirection in it than of candor and appreciation, the step which Christian civilization took at that time, so to speak, from Heaven towards earth, from its institutional aloofness towards nature, was very real and very important as a first positive step both towards an eventual adaptation and towards natural science. Appearing as compromise and intrigue, it nevertheless was in service of an honest purpose. In clear evidence of something more than mere defense and selfish intrigue the Church of the time had its liberals as well as its conservatives and in good time came the Reformation and the great schism which brought a distinct and positive candor towards the human and natural. Followed the great era of

objective science, of democracy, industrialism, machinery, in a word of social, moral and political as well as intellectual naturalism in place of the earlier aloofness and unnaturalism.

But now, while after a fashion every one does know this story and in it can see man slowly but surely finding himself in nature, adapting himself to his environment, there are aspects of the process, as so recounted, and particular stages of it, which need special consideration.

In the first place, how rose at all that unworldly institution in which so long civilization dwelt aloof? Historically, whatever be any one's religious or theological accounting for it, it rose as a device of safe retirement, an ark some very properly have called it, when with the collapse of the ancient civilizations, notably of Rome, the great floods came. As those floods rose, civilization withdrew into itself, gathering its acquired ways and protective covering about it. Did not the great father St. Augustine proclaim his "City of God," the Church, and did not the Bishop of Rome come into his papal power, as Rome approached and finally reached her fall? As a device of adaptation the Church doubtless seems hopelessly negative, adaptive through withdrawal rather than through direct action and even suggesting one of those strategical retreats of which we were hearing so often a year or two ago; but, negative or not, it proved not only a wonderfully effective device, strategically wise for its day and generation, but also—and this I would now specially stress—a most valuable preparation for the more aggressive and openly practical enterprises that came later. The very barbarians who overwhelmed Rome it took captive. It assimilated to itself all of western Europe and by its rites and offices, its education in all departments of life, its splendid organization, it really made our modern rationalistic or scientific naturalism the true lineal descendant of its institutional supernaturalism, possible. Very much as alchemy developed into chemistry or astrology into astronomy, so its régime, moral and intellectual, strangely enough only the more rigorous because of the magic or the supernaturalism upon which it counted, eventually made possible the larger and only more general rationalism and mechanicalism which was inaugurated practically with such achievements as the successful navigation of the open sea and theoretically with the successful use—as for example by Galileo—of the mathematical equation in explanation of natural phenomena.

Few have seemed really to appreciate that, practically or theoretically, the change from a supernaturalistic, militaristic institution to a mechanical nature was only the outcome of a

generalization by which the spirit of the institution sought and found itself in the world as a whole. Such, however, appears to have been the fact and this fact in a peculiarly significant way reveals the adaptation-value of the great medieval institution besides showing the active and serviceable presence of philosophy and generalization. It shows, too, that the important progress made in the eighteenth century, when the naturalistic rationalism succeeded the old order, was really evolutional rather than merely revolutional in character.

That the modern era got its schooling in the Middle Ages, Protestantism from Catholicism, democracy from monarchy, industrialism from militarism, the mechanic from the soldier, rationalism from apologetics, mechanicalism from dogmatic institutionalism, inductive science from deductive, mathematics from positive legalism, even moral independence and conscience from the Church and its confessional, needs to be clearly recognized and appreciated. The pupil, moreover, learned his lesson well. But, not to prolong this chapter of my story, the new life did spring out of the old and an age of institutionalism gave place to an age of rationalism. Machinery, authority, causation all turned universal; creationalism yielded to a general mechanicalism; theology opened into science.

And with the coming of the era of science, institutional ritual and law being subordinated to natural law, our story of Christendom's progressive adaptation to environment gets somewhat easier. Certainly any one can appreciate the progress in the change from mathematics and mechanics to biology or in that from biology to anthropology and psychology. With each step, as has been pointed out already, man who in the Church had belonged to another world rather than to this and who had lived consciously and deliberately with reference to the hereafter gets ever nearer this or ever more truly in-and-of this. At first we see him with mechanics coming into a general but still only formal, then with biology into a distinctly more vital relation to this; until with the last, psychology, he is in an intimate and personal relationship. Certainly philosophy's present-day psychologism, as shown in pragmatism, experimental idealism, the many types of realism—radical, scientific, critical, "new," what you please—has quite outdone biology in its intimations of the unity of man and nature; because it has made, not merely organically living, but also consciously living man and nature most vitally and essentially one. Consciousness carries a far closer intimacy than organic life. Also for full understanding it should be remembered that today, quite as truly as mechanics or biology, psychology is

to be looked upon as one of the real physical or rather natural sciences.

In spite of all that has been said my meaning may not yet be clear. In the sequence of philosophy's disciplines: theologism, mechanicalism, biologism, psychologism, no such story as was promised may have appeared. Possibly, then, at risk of tedious repetition, it may be well with a change not of the subject-matter but simply of the angle of view to add the following. Four conceptions: institution, mechanism, organism and conscious being, the human individual or person, have taken, each its turn in the order given, at holding the center of man's interest in and understanding of nature and have marked each an important step in man's progress, as he has taken possession of the earth. To science, even including under this term theology which has been found to have its place in the sequence and, as now I would add, including also jurisprudence which characteristically is science of the institution as temporal, formal, positive, theology being characteristically science of the institution as eternal and vital, as originally purposed and created and as maintained—to science, I say, the conceptions: institution, mechanism, organism and person, each one as it has come up, have referred to something special and definable, tangible and capable of positive identification. Definition and such identification are conditions of science. But in each instance, not less from demands of practical life than from those of theory, the handmaid philosophy has been in attendance and her service, faithful if not always appreciated, has induced a generalization from the particular and positive conception involved and so has opened the way to the next conception. Thus, as we have remarked, a dogmatic, supernaturalistic institutionalism gave place to a general and naturalistic mechanicalism. Even the creating cause and propelling force, acting from without, of the institution was made general, as is shown in mechanicalism's substitution of universal causation for the institution's dogma of only-once-upon-a-time causation or creation.[2] But also, thanks again to the service of philosophy, the conception of mechanism in its turn gave place to that of organism. What is an organism but general mechanism or mechanism become versatile, that is, natively mobile or active with the freed mechanical principle and so no longer bound to the routine of any single application of that principle, capable in other words of indefinite mechanical adaptations.

[2] Physical science's long dependence on the two principles, uniformity of *nature*—no longer just of the institutional life—and *universal* causation, has thus a most interesting historical antecedence.

In the person, finally, the generalization or the versatility is seen to be developed still further by the addition of conscious initiative to the adaptability.

So in the four conceptions, as in the four isms, we now have our story before us. The story does show, too, what was promised for it, namely, man's progressive adaptation to the natural environment, his gradual finding himself in nature, and it shows also in each important episode the constant service of philosophy, whose generalizations have really served science; not servilely, but in the vital way of inaugurating the new epochs instead of merely maintaining the old ones. Again, in indication of what the progressive adaptation and generalization have implied, the story shows an increasing versatility for human life. But particularly interesting as is this association of progressive adaptation with increasing versatility, it is for us here only to note how the history reveals philosophy as vitally, although never formally, scientific and thus shows how that lie about philosophy being unscientific was only a great truth in masquerade. That, unfortunately, professional philosophers have often neglected their great opportunity and even flagrantly abused it or that scientists themselves have sometimes turned philosphical and have so led their own science out of its particular captivity does not affect the matter at all.

Now, once more as to the progress from mechanicalism through biologism to psychologism, there is an interesting incident of the movement that merits some attention, although easily too much might be made of it. Not only does mechanicalism mark an early stage of the adaptation-process, in which man and his environment can hardly be said yet to have come into a close or vital unity, but also the early science of mechanics, especially as appealing to philosophy, was what might be called a gross mechanics, dealing as it did with the great bodies of the solar system, that is, with the gross and also the more distant factors of the physical or natural environment, Psychology, in sharp contrast, as the latest of the sciences, is concerned with the minute and very closest factors. For psychology the environment is no glorious and wonderful firmament, no orderly procession of the planets, impressive for the distances and the orbits and expressive of a great law, but is, instead, a close, sensuously felt and very real presence; not a matter, then, of distant view and contemplative wonder, but something immediately at hand.

> No wondrous whirl of earth or sky,
> Nor stars in ordered place:
> But nearer things, like wind and rain,
> That beat against one's face.

Such a difference, I say, between the earlier mechanics and the later psychology must not be taken too seriously; but, however superficial it may seem to be, it does in one more way show the progress of adaptation.

But, finally, of psychology and psychologism something special needs still to be said, lest there still be misunderstanding. Psychology is "science of conscious life" and in this character it might be taken for almost anything, including even the old-time "science of the soul." Present-day psychology, however, while truly being "science of conscious life," is also at the same time the latest natural science, as has been pointed out here. It is a natural science and to it such special branches of natural science as biology, physiology, neurology, are of greatest mediate value. It is itself, too, an experimental and laboratory science and so through mechanical methods and instruments it depends, albeit only mediately, on the narrowly physical as well as on the biological sciences. Accordingly in its character of being a natural science even while it is also psychology we may see the peculiar value of its coming at the close of the historical sequence. For it man and nature are indeed one. In fact its two characters or rôles, psychology *and* natural science, are so mingled that, just to allow ourselves a little amusement, its situation is not unlike that of the man who unfortunately or fortunately was so very thin that he could never decide, when in pain, whether he had a backache or a stomachache. Current philosophy, essentially psychologistic, knows not whether it is idealism or realism. A most happy predicament!

It would be interesting to close the story of adaptation as told here with some discussion of the moral and political, social and economic changes that have come with the changes in isms or in ruling conceptions. About an association of one group of changes with the other there can be no doubt. Science and philosophy are hardly epiphenomena. They are hardly accompaniments of the history of human affairs without being really and vitally of it. Their very reflection of the process of adaptation would seem to be conclusive evidence of this, if evidence were needed. But the story originally promised has been told and other matters, however interesting, must be left for another occasion.

THE PROBLEM OF THE HISTORY OF SCIENCE IN THE COLLEGE CURRICULUM*

By Professor HENRY CREW

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IF one were asked to describe in a single phrase the present-day position of the history of science in the college curriculum, I think he might fairly call it the "Ugly Duckling" of the program. For while it is just now receiving the treatment of an orphan, and the department of history has never seen fit to take this fledgling under its wing, the young bird has perhaps nevertheless all the possibilities of becoming a swan.

I hope to make my meaning clearer by saying a few words about the place for such a course, about the character of the course, and finally about the man for the course. In fact, I wish to offer a brief plea for a more human treatment of the fundamental sciences than they are now receiving, and I want to suggest that the most effective method of accomplishing this result is the introduction of courses on the history of science.

1. *First*, as one glances down the average college curriculum, and the faculty list, he may, I think, fairly admit that political and social history are well handled by men who are competent specialists—the men, indeed, who constitute the membership of your association.

Of the history of English literature the same may be said.

In the case of foreign literature, it is only after the student has passed beyond the technique required for easy reading, that he is introduced to the historical development of either the language or the literature. Economics, philosophy and psychology are frequently, at least, presented in the order of their chronological development, *i. e.*, in the historical order in which the facts were discovered—the order which Darwin has taught us is the natural order.

The modern college offers to its students practically only four lines of training—four topics which one might call "the modern quadrivium." These are

(i) Languages and literature.
(ii) Historico-political study and economics.

* A paper read before the American Historical Association at Cleveland, December 31, 1919.

(iii) The Philosopical group, including psychology, education, religion, logic, and mathematics.

(iv) The experimental and observational sciences; or, if you prefer, the physical and natural sciences.

Of these four topics, it is only the last mentioned which is *not* already receiving a more or less distinctly historical treatment. The typical natural sciences are, I suppose, *Zoology* and *Botany;* the corresponding physical sciences are *Physics* and *Chemistry.* These four sciences constitute the foundation upon which the other sciences rest; or, if any one prefers, they are the sciences which are in an especial way ancillary to all the others.

Physiology, hygiene, bacteriology, medicine, etc., naturally develop from biology, just as astronomy, geology and engineering come from physics and chemistry. Each of these four fundamental sciences does, of course, receive historical treatment in numerous curricula; but in many institutions no such course is offered. Professor W. F. Magie has published a complete treatment of physics written from the historical point of view. It might be called historical physics rather than a history of physics; since the emphasis is rather upon the clear and careful statement of the principles of the science, than upon its history. A combined course on the natural and physical sciences is offered by Professors Sedgwick and Tyler. My colleague, Professor Locy, has for many years given a very successful course on the history of biology. Numerous courses in the history of chemistry are given: more than twice as many as are given upon any other of the four fundamental sciences. Some are also offered in the general history of science, such as those by Professor L. J. Henderson, of Harvard, by Professor Walter Libby, of Pittsburgh, and by Dr. George Sarton.

The need for courses in the history of science appears to lie rather in these four fundamental sciences than in any subject outside: this, partly because the early history of these four subjects covers practically all the other sciences, and partly because the history of science, in general, appears to be quite too large a topic for one man to treat intelligently and sympathetically.

The theorem then which I propose is the following: Every college of liberal arts owes it to itself and to its students to offer at its earliest opportunity courses in the history of botany, zoology, chemistry and physics, in addition to the numerous historical courses already offered in other branches of the modern quadrivium.

2. Passing now to the character of the course which should be presented, this is, manifestly, always a question of time, place and man. Nevertheless, there are certain considerations which have, I believe, a wide validity among American colleges.

It was my privilege a few weeks ago to attend a lecture on *general physics* given by a young man who was offering the course for the first time. I was present on invitation and the comments which I am now about to make are precisely those which I gave to the young man himself at the close of his lecture.

The discourse was well illustrated by experiments; his demonstrations were clever and orderly; his explanations were clear and correct. He was evidently master of his subject, which on this particular morning happened to be *elasticity*.

But Hooke's Law was demonstrated without the slightest reference to that crabbed and crusty, but tremendously clever old bachelor, Robert Hooke, who lived in Gresham College and entertained the Royal Society of London so frequently and faithfully with the latest scientific results obtained sometimes by his own labors, sometimes from the labor of others.

This young instructor next proceeded to define Young's modulus and to derive the algebraic formula for it, without so much as a mention of that brilliant London physician, who at the beginning of the nineteenth century was perhaps the most variously accomplished man of science in England, the young Quaker, who as a medical student at Göttingen found ample time, between the more serious duties of a strenuous program, for lessons in dancing and horseback riding.

The elasticity of air was next expounded under the caption of Boyle's law, without any one of the one hundred and fifty auditors suspecting the existence of that charming old Irish bachelor, who largely held together and inspired the "Invisible College" out of which the Royal Society grew; the author of the "Skeptical Chymist"; "Robyn," as his sister called him; the intimate friend of Evelyn, Pepys, and Newton; director of the East India Company.

One can imagine that in his succeeding lecture my young friend would deduce and demonstrate with precision and elegance, the laws of collision, while his students are kept completely in the dark as to the three remarkable men—men of the first order—Huygens, Wallis and Wren—who first established these laws.

This bit of experience is mentioned, not in criticism of this young man, of whom I am an ardent admirer and to whom I have already said all I am saying to you, but rather to raise

this question: Is science in America to be forever presented as a set of abstract principles, a set of generalizations, derived, it may be, in the first instance, from experiment or observation, but now formulated in the most impersonal way possible? Or is science to be treated as a distinctly human achievement?

Are not experimental results simply the facts which human beings have deciphered from the scroll of nature? Are the laws of physics and chemistry anything more than human expressions, adapted to finite human capacities, and accepted because of their convenience in human conversation? Is a theory in astronomy anything more than the "present policy"—to use Sir J. J. Thomson's phrase—proposed by some human observer for convenience in making prediction for later human observers? Are the bodies of plants and animals anything more to the student of biology than the source-books from which some human investigator has unraveled the laws of development and hygiene—the laws of birth, growth, death and disease? Do the various extensions of physical and natural laws to include new observations mean anything more than the fact that present investigators stand upon the shoulders of their fathers and thus acquire a wider and deeper vision?

If now this edifice which we call modern science—this body of "impersonally verified truth"—borrowing Professor Minot's excellent phrase—is an incomplete human structure, if it is after all merely a record of human thought, a formulation by the human mind, tremendously useful to the physician in the prevention and cure of human disease, valuable to the engineer in securing human comfort and safety, and human leisure for other forms of human activity; if, I say, science has all these human elements in it, why may it not be so presented to the student?

Let us, of course, concede that Dante's *Comedia*, with its human inferno, filled with striking pictures of all human qualities, the frail and the strong, the good as well as the bad, is a rare and powerful stroke of the human imagination. But what shall we say of the investigations of Copernicus and Kepler and Aristarchus, reaching out into vast space and finding unheard of orbits, speeds and distances?

Let us concede that Homer's story of Achilles going out after Hector is one of intense human interest. But what shall we say of the fight which Galileo maintained from boyhood to death, in such a skillful manner as to allow him, meanwhile, to accomplish his two great works and get them through the press?

Let us concede the lofty flight of the human imagination in

which Milton casts Satan out of heaven. But what shall we say of the many superstitions cast out of the human mind by Milton's contemporaries—Huygens, Newton, Pascal, Harvey and Leeuwenhoek?

We are all glad to recognize the rare and human beauty of Tennyson's verse; but let no one imagine that he is either nodding or stepping down when he sings the story of evolution. Is the exquisite flight of genius in which his contemporary, Clerk-Maxwell, describes the essential features of that wonderful human convenience called wireless telegraphy, a quarter of a century before the art was realized in experiment, any less appealing?

Now having made all these concessions and as many similar ones as you like, does there not remain sufficient human interest in science to justify its presentation as a human achievement, rather than a heartless, bloodless, colorless, body of cold rigid fact? Tragedy and comedy, pathos and humor are, of course, never found in nature. We must seek them in human nature; the history of science is full of them. "The fairy tales of science and the long results of time" with which Tennyson nourished his "youth sublime," offer as large a field for the imagination as any other theme of poetry; the one difference lies in the fact that the scientific imagination must be bridled by reason; but this curbing of the imagination by reason is all that we mean by clear thinking; and clear thinking is the goal of all our work.

Now, I have not even mentioned the "humanities." I shy at the term, only because I fear it has come, in many quarters, to mean almost the exact opposite of the spirit which prompted the composers of Greek and Roman literature, and also the opposite of that which was intended by the men who introduced the term in the fifteenth century. Nevertheless, I trust, I have fairly indicated the possibility and desirability of treating science in a humanitarian manner and of making it one of the real humanities of the modern curriculum. If accuracy of judgment and clearness of thought are to be sought in the new quadrivium, they will be found most easily and most frequently through the study of language and science. It is especially up to those of us who teach the history of science to present its human aspects—which are not for a moment to be identified with its merely practical and commercial aspects—and thus redeem the word "humanity" from the narrow sense in which it is employed at Oxford and in the Scottish universities.

3. Let us now pass to the man who ought to offer such a course; that is, a course which shall present science as an evolution of the human mind—as a growth rather than as a finished product. There is a helpful French proverb to the effect that "at thirty every man is either his own physician or a fool," suggesting that at an earlier age he is too busy with other matters to care much about his own health. It is somewhat so with the young man who has just made his doctor's thesis in science. He is so much absorbed in the beautiful unity which he has recently discovered in his subject, and so eager to get a still wider and firmer grasp of his specialty that he finds little time to spend upon its developmental history.

With the recently appointed assistant professor, the circumstances are not very different. He also has little time for the past. "Dead men ride fast horses." He is too busy with his own research along his chosen line. He can not leave it except for the perfunctory teaching of those courses which, in common decency, he must offer. If one sugests to him the possibility of his offering a course in the history of his topic, his reply resembles a stanza in which Mr. Kipling once declined an invitation to dinner from the boys at Yale.

> When you grow older, and skin your shoulder
> At the world's great wheel in your chosen line,
> You'll find your chances, as time advances,
> Of taking a lark are as slim as mine.

This was indeed my own view for many years. Time spent on the history of physics was time spent on a luxurious lark. "The years go fast at Oxford."

The full professor is not far from forty years of age. With him the circumstances have begun to be a little different. The connection of his own work with that of others is more evident. The philosophy of the subject is interesting him more and more. He is now aware of the fact that the lives of the founders of the Royal Society are inseparable from the civil wars of England, the great fire and the great plague of London; that Darwin and Kelvin are just as essentially features of the Victorian era as are Gladstone and Tennyson; that Pascal and Torricelli and the Accademia del Cimento are inseparable from the religious history of their times—the age when science was supported, if at all, by royal patronage. "Knowledge comes, but wisdom lingers." Here then is the man who ought to teach the history of science. One who is familiar with the technique of investigation. One who knows the mode of thought employed

in research. One who is willing to take the pains and pay the price of making some small contribution to human knowledge: one who is able to bend the English language to his own purpose.

This man will be too keenly aware of his limitations to undertake the history of *all* the sciences, and will find the available hours brief enough for a history of his own science. An illuminating confession along this line is the public address given by the distinguished editor of the *Review* when, overwhelmed with the rapid development of mathematics, he broke off in the midst of a brilliant university career to take up newspaper work. A similar confession came to me a few weeks ago from a man who had left his favorite field for ten years of executive work, only to find on returning to the field that the landscape was covered with a new and entirely unfamiliar growth.

The outstanding difficulty in the way of any man of science giving a historical course is that scholar's instinct which tells him that, as a rule, he lacks the proper historical background, and does not have the easy confidence of the man who has been long in training at general history. Nevertheless, if we can find men of breadth and vision, men of at least forty years of age, who are willing to present the developmental histories of the fundamental sciences, especially physics, chemistry and biology, and to present them in such a way that they will furnish the student with a generous culture, and put him *en rapport* with his environment, the place of our subject in the college curriculum will soon be established.

Nor is the proposition one which we need fear to urge upon our university presidents, our colleagues or our students; for just as water is the great, common and dominating feature of the globe, so is science the one common feature of all nationalities and all civilizations. Science does not differ from nation to nation as do language, religion and politics. The history of science is therefore something almost as wide as the human race and deserving of humanitarian treatment.

THE PLANETESIMAL HYPOTHESIS IN RELATION TO THE EARTH

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INTRODUCTION

CHAMBERLIN'S recent book on "The Origin of the Earth" was welcomed by geologists as the most complete statement yet made for the planetesimal hypothesis of the origin of the planets.[1] Barrell has given a convenient summary of the hypothesis, in the following words:

> The volume of a star [the sun] represents a balance between expansional and condensational forces acting on a vast body of gaseous nature. On the approach [of another star] their mutual gravitation would produce tidal forces diminishing their self gravitative power along the line between the centers and give the expansive forces opportunity to rise to explosive violence along that line. This tidal force is actually greatest at the centers and would lead to a very deep-seated disruption. The gas bolts shot out would, owing to viscous resistances, be pulsatory, and separated nuclei would therefore be expelled. These nuclei and the associated dispersed matter would, on the nearer side, be dragged sideways by the passing star. On the reverse side the symmetrical tidal protrusions would be left behind, the sun being dragged more than they. The result would be a spiral nebula, a form which would meet the dynamic demands of the existing solar system. . . .
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> The building up of the planets is believed to have followed three stages: first, the direct condensation of the nuclear knots of the spiral into liquid or solid cores; second, the less direct collection of the outer, or orbital and satellitesimal matter; third, the still slower gathering up of the planetesimal material scattered over the zone between adjacent planets. This third factor in Chamberlin's view is regarded as very important and he believes this diffused matter contributed much of the earth substance, very slowly and in a dust-like form. This is one of the critical points in the details of the theory, unessential to the larger framework, but upon which turns much of the development of the following argument. In earth-growth the denser planetesimal dust, Chamberlin argues, tended to be somewhat segregated into the primitive ocean basins and served to maintain in them, as the earth was built outward, a greater density than in the elevated zones between. . . .
>
> The earth is conceived as beginning to hold an ocean by the time it contained 30 or 40 per cent. of its present mass. . . .
>
> The particles of radioactive matter [in the earth] would tend toward

[1] T. C. Chamberlin, "The Origin of the Earth," University of Chicago Press, Chicago, 1916.

local heating and fusion. Thus they would be progressively concentrated into the outer shell of the earth by the rising of igneous matter. Pulsatory stresses from body tides and from shrinkage are regarded as the chief agents leading fused matter outward and serving to maintain the earth's body in solid form.[2]

On the astronomic side this conception of the solar system represents one of the grandest achievements of modern science. The distribution of masses and momenta, the directions of revolution and rotation, and the constitution of each member of the system, so far as ascertained, are explained with such a degree of probability that astronomers are becoming more and more impressed by the planetesimal hypothesis. However much increasing knowledge may change premises and conclusions, the critical and creative work of Chamberlin, Moulton, and their associates has resulted in stimulus to many minds and marks a permanent advance toward a final understanding of the earth's beginning.

Chamberlin was led to his great idea while studying ancient climates, and it is natural that he has attempted to apply his cosmogony to that later part of terrestrial history which is covered by geology proper. He has recognized the exceeding difficulty of this extension of the hypothesis beyond the astronomic limits, but has courageously attacked the problem as it affects the general distribution and shapes of the existing continents and ocean basins; hence the making of assumptions which have no vital connection with the splendid cosmogony itself. Some of the subsidiary assumptions are doubtful, if not quite inadmissible, and it now looks as if general recognition of Chamberlin's working hypothesis would have been hastened if it had been announced without direct reference to the later, geological, history of our globe.

One doubtful postulate is that the earth has been essentially solid since the time when it had less than half its present mass. To a discussion of this point the present paper is devoted; the postulate is hard to reconcile with the main planetesimal hypothesis itself, on the one hand, and with leading facts of astronomy and geology, on the other.

Some Implications of the Planetesimal Hypothesis

Neither the mass, nor the temperature, nor the dynamics of the original earth-knot or nucleus are deducible from the root premise of expulsion from the sun. According to some astronomers, the visible spiral nebulæ are not homologies of the plane-

[2] J. Barrell, *Science*, Vol. 44, 1916, p. 241.

tesimal nebula. In any case one can not infer from the spirals, even in rough measure, the state of the earth nucleus immediately after its expulsion. The general hypothesis gives no direct information concerning the ratio of the mass of the knot to the mass of the existing earth. Around the earth is now a "sphere" (spheroid) of control within which our planet's gravitative influence surpasses that of the sun. The sphere of control is roughly 5,000,000 times the volume of the earth. Within so great a space nearly all of the earth's matter might have been aggregated at the nuclear stage, in spite of the high temperature prevailing at the initiation of the earth-knot. If so, condensation of the earth-knot by its own powerful gravitation would be rapid, with the consequent speedy increase of temperature. Initially hot enough to be completely gaseous, the nucleus radiated much heat, but this effect on temperature was at least partly offset by the development of heat through self-compression and chemical changes. A very large part of the initial heat and of the original potential energy would have to be lost by radiation before a liquid state were assumed and still more before a solid crust could be developed. According to Lane's law, radiation and consequent contraction would actually raise the temperature of the knot if its gas behaved like a "perfect" gas. The potential energy of such a system is far from being measured by the amount of the contraction. Doubtless a much greater part of the potential energy would manifest itself in the form of heat given off during chemical reactions in the nucleus, which was initially composed of highly dissociated elements.

In short, the original earth-knot was, by hypothesis, a true furnace. Its generation of heat must have long continued, even if the initial mass were only one quarter of the globe's present mass. The vital question arises as to whether the gaseous knot would be solidified by cooling before most of its accretion was accomplished. *Rates* of heating, *rates* of cooling, and *rates* of accretion, as well as the initial mass and temperature of the knot are involved, and the general hypothesis bears no implication concerning any of these quantities.

Chamberlin appreciates this fact and concludes that "the temperature of the innermost core of the earth" must remain "an open question." He also states that "the mass of the planetary nucleus may have been so large and the ingathering of the planetesimals may have been so rapid, by hypothesis, that a molten or even a gaseous condition could have arisen. In the case of the larger planets such a primitive state is quite within

the limits of the probabilities. The case of the earth is debatable."[3]

Assumption of the Earth's Early Solidity

Yet, notwithstanding his own unescapable conclusion, Chamberlin believes that the earth, with a mass only about one third of its present value, was already well crusted, if not essentially crystalline to the core. He assumes that a water ocean could then lie on the earth's surface, and that the heat of self-compression, chemical heat, and heat generated in radioactivity have never sufficed, since this embryonic stage, to melt the surface shell of the globe. With these assumptions, which are not implicit in his main, astronomic hypothesis, Chamberlin proceeds to picture the juvenile shaping of the earth, in the longest chapter of his latest book. Further difficulties appear as the speculation is developed, leading to other unproved assumptions. The latter are not of immediate concern, since they rest on the conception of early, and thenceforth permanent, solidity for the earth, which is the thesis specially questioned in the present note.

Testimony of the Other Planets

The general hypothesis assumes similar origins for all the planets. Jupiter, Saturn, Uranus, and Neptune have densities either a little less than that of water or a little greater, contrasting with the mean density of the earth, 5.5. There are apparently only two possible explanations of the contrast. The outer planets must be greatly expanded by heat, or else they must be composed of hydrogen or other elements of low atomic weights.

Each planet represents a major belch from the sun and yet also a minute fraction of the sun's substance. Now studies of the sun's photosphere, "reversing layer," and "spots" show that its surface shell, down to a depth of many hundreds of miles, is composed of both heavy and light elements. Heavy elements are likely to be still more abundant in deeper shells. We can not assume that the sun, because of higher temperature, was a "hydrogen" star when the planetary belches took place, and that the gas-bolts were shot out from the outer layer of hydrogen. This possibility is at once excluded by the facts known about the constitution of the four inner planets, the asteroids, and the satellites of the planets. Thorough mixture

[3] T. C. Chamberlin, "The Origin of the Earth," Chicago, 1916, p. 164, and "The Tidal and Other Problems" (Carnegie Institution Publications, Washington, 1909, p. 18).

of heavy and light elements in the sun at the present time is plainly due to convection and explosion.[4] Both actions would doubtless have been still more intense when the sun was hotter. If, as Chamberlin thinks, the belching were due largely to explosions originating in great depth, heavy elements could hardly fail to enter into the composition of all the major belches. The greatest belches should have tapped deeper layers than those tapped by the weaker earth-belch, giving a larger percentage of heavy elements to the four outer planets.

On this point Chamberlin writes: "The distal portions of the protuberances would be obviously formed from the superficial portions of the sun, while the later portions of the ejections forming the proximal parts of the arms would doubtless come mainly from lower depths, and hence probably contain more molecules of high specific gravity."[5] But is that conclusion justifiable? If all of the planetary material were put back in the sun, the sun's diameter would be little changed; its mass would be increased by less than one seventh of one per cent. If a mass equal to either Neptune or Uranus were removed from the sun's surface shell, the depth of the layer known to be now affected by powerful convection would be decreased by only a small fraction. The supposition that, at the birth of the planets, convection did not affect the sun's layer which was disrupted, is not easy to reconcile with the sun's present condition. To suppose that deeper layers were not tapped is to exclude the strong influence of explosion, a basal postulate of the general hypothesis. Moreover, the smaller the mass ejected, the more superficial would be the solar shell involved. All these considerations make it difficult to believe that there would be any drastic or systematic variation in the material ejected successively from the sun. One might even raise the question whether the general hypothesis demands that the earth-belch really followed in time the Jupiter or Uranus belch. If, on the contrary, the earth-belch were the older, it should, according to Chamberlin's principle above-quoted, have density lower than either of the other two; lower, too, because the earth-belch was the weakest of the three. Finally, the densities of at least two of Jupiter's satellites are too high to be explained by the hypoth-

[4] The experiments of H. Bénard (*Rev. gén. Sciences*, Vol. 11, 1900, p. 1261) suggest that the granulation of the sun's surface may be due to the development of a cellular structure which is expected in any fluid layer uniformly affected by convection.

[5] T. C. Chamberlin and R. D. Salisbury, "Geology," Chicago, Vol. 2, 1906, p. 58.

esis that their parent belch was made of pure hydrogen or of hydrogen mixed with helium.

Much more probably every major belch from the sun was made up of elements now engaged in the solar tornadoes—calcium, iron, barium, sodium, magnesium, silicon, etc., as well as hydrogen and helium. In fact, from a passage quoted above, Chamberlin seems to have abandoned his early view, now favoring the conclusion just stated. Perhaps yet more surely than the Laplacian hypothesis, the planetesimal hypothesis demands that all planets shall have a large proportion of elements with high atomic weights. If so, the outer planets must have very high temperatures, as so long held by astronomers.[6]

We have, then, half of the planets still so hot as to be gaseous, although, by hypothesis, they are nearly as old as the earth and are probably composed of material which is much like the average material of the earth.[7] At this late day the four outer planets must be losing heat many times faster than the earth is losing heat through a solid crust and still they are incomparably hotter than our globe. According to the planetesimal hypothesis, they are so hot because of their size. If the common mechanism produced in four full-grown planets temperatures sufficient for nearly complete volatilization of highly refractory substances, temperatures persisting after more than one hundred million years, is it reasonable to assume that the mechanism failed to produce the much lower temperature needed for surface liquefaction of a fifth planet a hundred million years ago? Do not these homologies suggest yet more—a gaseous condition for the earth after it had attained its present mass?

In summary, the planetesimal hypothesis leaves indeterminate most of the essential factors affecting the earth's successive temperatures, namely, the ratio of nuclear mass to

[6] Of course density can not give accurate intimation of temperature. Saturn, for example, with a little over half the density of Jupiter (0.7 against 1.3, water being 1.0), is not necessarily the hotter. Moderate differences in chemical constitution, together with differences in internal pressure, must also enter into the causes for the contrast.

The reasoning is not affected by the possibility of a solid core for each of the outer planets. The core must be relatively minute, for otherwise the average density would be too high to match the facts. With correspondingly great depth for the planetary atmosphere, involving pressures of tens of thousands of earth atmospheres, the average density of the planet could be low only in case the main, gaseous part of its body had high temperature.

[7] The approximate identity of age is implied by the basal postulate of disruption, for a visiting star would vitally affect the sun for only a few years, at most.

planetary mass, the initial temperature of the earth-knot, the rate of accretion, the heating factors, the cooling factors, and the absolute time involved. Hence the present condition of the other planets ought to have special attention by any one who attempts to trace the earth's history down into "Archean" time. Perhaps we can hope for no better evidence in nature on the subject of the early temperatures of our globe.

An Early Crust a Blanket on the Earth Furnace

If, however, radiation did actually overtake heating in the young earth, with the development of a solid crust, the general hypothesis implies the likelihood that this crust would be but temporary. So far as densities are concerned, it might have been stable if the earth had already, because of fluidity, become stratified by density. On the other hand, the crust, an efficient blanket, must have brought radiation to a very low minimum. Later, considerable accretion of the earth nucleus could not fail to develop new heat by self-compression and chemical rearrangements under the new, ever-changing conditions of internal pressure. The changing conditions would affect material at all depths. The heat waves so generated would pass outward with great slowness, for convection was largely in abeyance if the earth were layered according to intrinsic density of its materials. A relatively moderate heat-wave of the kind, moving outward for but a brief time, would suffice to re-melt the crust. Each time that the surface shell became fluid, gravitative differentiation would be more perfected near the surface, with resulting retardation of convection. On one of the reasonable assumptions regarding the young earth, therefore, the planetesimal hypothesis seems to demand a cyclical or rhythmical change of state for the earth's surface shell, analogous to that observed in the lava lake at Kilauea or in other typical volcanic vents.

Be it observed, nevertheless, that the general hypothesis, as announced, does not necessitate belief in crustification (or in solidification at any depth) of the earth until it had attained its present mass.

Testimony of the Moon

The volcanic nature of the lunar pits and maria is generally credited and seems to be implied by the planetesimal hypothesis. If the pits and the vast areas of the maria were due to the impact of bolides, these bodies would, by hypothesis, be planetesimals. They would have been practically the last to fall into

the lunar nucleus, for the visible depressions are not appreciably veneered with planetesimal particles of smaller dimensions. Similar masses would have fallen into the earth during the last stage of its growth. Yet nowhere on continent or in ocean basin is comparable topography to be found. The progress of erosion can hardly account for the disappearance of every trace of such gigantic features. Moreover, the symmetry of each lunar pit does not agree with the impact hypothesis, if the great bolides were planetesimals, added to the moon's mass in the normal way.

If, by fair interpretation, the planetesimal hypothesis implies a volcanic origin for the lunar depressions, the main hypothesis also implies that, after reaching full size, one of the smaller aggregations in the solar system had internal heat enough to permit eruptivity on a scale vastly superior to the scale of volcanism on the present earth. In more or less close succession all parts of the moon's surface seem to have been affected by igneous eruption. The colossal lava-floodings of the maria have been accompanied by subsidence of the pit-covered crust in the corresponding areas, suggesting (as in the earth's similar cases) that the flooding lavas were drawn from a non-crystalline substratum close to the moon's surface.

According to the planetesimal hypothesis, the moon's volcanic heat was generated largely by self-compression and chemical rearrangements in a body with mass only one eightieth of the earth's mass. The facts are not opposed to the conception that the moon was itself actually molten at the surface just before the satellite took on its present characteristics. In any case the total heat generated in the moon must have been enormous. By hypothesis, the total heat generated in the growing earth-knot was many multiples of 80 times greater. Can one doubt that general volcanicity in the one case would be fairly matched by complete superficial fluidity in the other?

CAUSE OF THE EARTH'S RIGIDITY

The combination of the facts known about the solar system thus interpreted by the planetesimal hypothesis furnishes a cumulative argument in favor of assuming a molten or even gaseous state for the earth's surface shell after our globe had grown to full size. Chamberlin's selection of a strongly contrasted possibility of his cosmogonic scheme is due in part to overemphasis on some elements of the scheme, especially those contrasting with essential features of the Laplacian cosmogony.

Other reasons are found in certain assumptions based on modern geophysical studies.

In the first place, he stresses the familiar principle that the melting temperatures of rock minerals are raised by pressure. Again it is a *rate*, the rate of the raising, which is absolutely vital to his argument. But it will be long before the relation of pressure and melting temperatures for the earth's core materials at their actual depths can be fixed. Meantime, one thing seems certain: pressures hundreds of times greater than those inside the earth are unable to cause the crystallization or even the liquefaction of most of the sun's substance; else the mean density would be very different from what it is. Not much weaker is the belief of astronomers concerning the non-solid nature of most of the materials in Jupiter, though these are under pressures far transcending mean or maximum pressure in the earth. Appeal to the principle here discussed has, in fact, been much overdone by many authors in their efforts to explain the earth's high rigidity.

Secondly, the proof of the earth's present high rigidity is taken by Chamberlin to mean solidity, that is, crystallinity, for the whole interior of our globe except for local "tongues" of melted rock. Even if this assumption were correct, it does not follow that the earth was similarly crystalline to the core during the period of accretion. But high rigidity does not necessarily mean crystallinity. With uniform laboratory pressures the viscosity of paraffin increases so much faster than the viscosity of nickel steel under the same pressure, that the hydrocarbon finally becomes more rigid than the steel. Rock glass, a supercooled liquid at ordinary pressure and temperature, is much more rigid than many crystalline solids. Under high, uniform pressure glass is many times more rigid than nickel steel. Under pressures of from 10,000 to 500,000 or more atmospheres, rock glass might attain, at high temperatures, degrees of rigidity quite competent to match the earth's stress-strain relations so far demonstrated. Neither seismic nor tidal vibrations within the earth demonstrate crystallinity for below the surface. If the earth's core is crystalline, the proof thereof must lie in some other direction, as yet unguessed.

For some geophysical inquiries it may be a matter of indifference whether the earth's rigidity is due to crystallinity plus pressure or to pressure alone; but Chamberlin's speculations on the shaping of the juvenile earth and on the cause of igneous action are critically affected by his choice between these alternatives.

Planetesimal Hypothesis in Relation to Igneous Action

The growing earth being a highly efficient furnace, by hypothesis, crystallinity could not be preserved for the interior materials, if the central heat were not quickly removed. To support his idea that liquefaction of the interior did not take place during most of the period of accretion, Chamberlin has imagined a special mechanism for the removal of heat. This involves selective mutual solution of the "more fusible" crystals and, through tidal kneading of the remaining solid materials, the upward streaming of the new magmatic "tongues" to the earth's surface. The heat is there dissipated by radiation and no longer threatens the stability of the solid state for the interior materials in general. The continuance of the crystalline state inside the earth is thus explained by the generation and rise of magmatic "tongues," and the generation and rise of the "tongues" is in turn explained by assuming a crystalline state inside the earth. The argument has some resemblance to reasoning in a circle.

Relative Rates of Generation and Transfer of Heat

The rise of the magmatic "tongues" is attributed by Chamberlin to tidal kneading of the earth's body. Barrell has pointed out the comparative feebleness of the tidal stresses now affecting the earth's interior. Those affecting the small, young earth at a time when the moon's material was still largely dissipated in the planetesimal state must have been much smaller still, unless the two bodies were then closer together. However this may be, the problem of the *rate* of heat transfer by the rise of "tongues" as against the *rate* of heat generation in the earth's interior is of first importance. The planetesimal hypothesis by no means implies that the special cooling mechanism just described was more efficient than the earth-furnace during the period of accretion. If the development of heat were more rapid than the heat loss, to the point of producing general fluidity, the imagined mechanism of extrusion and differentiation of material, as well as the mechanism of cooling itself, would be destroyed.

Nevertheless, Chamberlin prefers the view that there has been a stupendous sorting of the terrestrial substances through the expulsion of "tongues" working outward in an essentially crystalline earth. He writes:

> The mutations of the inner earth may be summarized as a single prolonged process by which the more fluent, solvent, and lighter material of the earth-body was concentrated toward the surface, while the more immobile, refractory, and heavier matter was concentrated toward the

center. The result may be pictured as a central core dominated by metallic alloys and a thick enveloping sphere dominated by silicates.[8]

The core residuum is supposed to have been originally crystalline, but recrystallized, without fusion, after the manner of the familiar metamorphic rocks. During these secular changes, "the arrangement of atoms and molecules in the heart of the earth was probably controlled in the main in the interest of the internal fixation of energy and was predominantly endothermic." Chamberlin assumes, on the other hand, that energy was not stored in the radioactive elements, which have continued their break-up throughout the earth's history and at all depths. Since radioactivity is taken to be the chief source of the latent heat represented in the molten "tongues," that assumption is necessary, but it is immediately seen to rest on an unsounded mystery. The conditions for the potentialization of energy in the radioactive elements are quite unknown, but those conditions may include very high pressure and temperature, such as those prevailing deep in the earth. The laboratory tests so far made are clearly inadequate to deal with the profound mystery, the existence of which prevents confidence in the extrusive mechanism imagined and in the allied argument for permanent crystallinity of the earth's core.

Dominant Magmas

Further, differential fusibility or solubility of planetesimal materials can hardly explain the visible eruptive rocks. The dominant magmas whence these rocks have come are the basaltic and the granitic, each of nearly uniform composition from continent to continent and from ocean basin to ocean basin, and throughout geological time. They are strongly contrasted chemically. *Both* can not be the "most fusible" or "most soluble" constituents of the earth. If one is a late differentiate of the other, field evidence of the splitting might be expected; there is none.

Nor does Chamberlin's speculation explain: (*a*) the fact that the bulk of the visible granitic rocks are intrusive, while the bulk of the basaltic masses are extrusive; (*b*) the fact that the pre-Cambrian basement terranes are on the average granitic, while the eruptives of the open-ocean floors are almost entirely basaltic or derivatives of basalt. The imagined "tongues" should not have risen from the earth's interior in this selective way. On the other hand, mere inspection of the quantities involved (including the oceanic salts) forbids the notion that the granites of the continents represent a re-melted residue of secularly weathered basalt.

[8] T. C. Chamberlin, "The Origin of the Earth," Chicago, 1916, p. 240.

Crustal Subsidence Connected with Eruption

Another fact not readily understood according to Chamberlin's mechanism of igneous action is the strong subsidence of the floors of major volcanic bodies and of laccoliths (lopoliths). The best theory of these sinkings refers them to the necessity of crustal collapse over the respective subcrustal areas whence the erupted magmas were drained. Each subsidence is readily comprehended if the feeding magmatic reservoir is a nearly or quite horizontal layer, local or general, below the crust. There is no reason to suspect that "tongues" from the deep interior would spread out at just the right depth to explain the many observed sinkings of the crust.

Eruption Largely Concentrated in Mountain Chains

Most of the post-Cambrian eruptivity of the continents is concentrated in orogenic belts, leaving the larger part of the continental surfaces free from igneous rocks. For example, the North American Cordillera has been many times, at long intervals, the scene of magmatic eruption, while the Great Plains region of Canada and the United States has witnessed little activity of that kind. Mid-continent ranges, like the Alps or Urals, and their respective environments suggest that this contrast has little to do with the meeting of continent and ocean basin. There is no apparent reason why magmatic "tongues" from the earth's core should so persistently reach or approach the surface only along the belts where the earth's surface shell is periodically wrinkled or broken. A genetic connection between orogeny and igneous activity must be assumed, but it becomes intelligible only on the supposition that the locus of eruptivity is in every case relatively close to the surface and not in the deep interior of the globe.

Eruptive Sequence

Finally, Chamberlin's speculation needs much supplementing before it can account for the general order of eruption in continental petrogenic cycles. The order is from "basic" to "acid," though often the sequence is closed by minor eruptions of "basic" magma. For reasons elsewhere detailed, this sequence seems to imply initial eruption of basaltic magma, followed, in batholithic provinces, by considerable assimilation of solid "acid" rocks, entailing differentiation of the new solutions.[9] The chief rock assimilated in batholithic chambers seems to have been pre-Cambrian gneiss of granitic composition. During post-Cambrian time the only primary magma erupted has probably been the basaltic; if so, all other pre-

Cambrian eruptives are of secondary origin. On the other hand, the older pre-Cambrian granites and gneisses, composing most of the continental plateaus, are not in similar relation to basaltic magma and must be regarded as independently erupted. If their eruption took place by the "tongue" mechanism, the composition of these melts must have been changed from the granitic to the basaltic during some part of the pre-Cambrian era, though long after the earth had reached its present size. No reason for such a systematic change is in sight if the "tongue" hypothesis of eruption be regarded as valid.

Conclusions

Many other facts of igneous geology are inexplicable on a cosmogonic theory which postulates a general solid (crystalline) condition for the earth during most of its growth. This is, however, not a necessary feature of the planetesimal hypothesis, which, apparently sound itself, points rather to the probability of a fluid state for the earth both before and for some time after accretion was completed. In a problem where so few of the essential elements can be quantitatively defined, the condition of the other planets, the satellites, and the sun is of primary importance. The planetesimal-nebula hypothesis is partly founded on the analogy of the visible spiral nebulæ. Analogy might be as fairly used to test it. However, the other planets are homologies, by hypothesis, and their testimony gives ground for deductions yet stronger than those from pure analogy. There is nothing in the dynamics of the planetesimal cosmogony which forbids belief that the earth long ago passed through a Jovian stage. To assume that its surface shell was not at least liquid when the earth attained full mass is seen to be hazardous when one reflects on the relatively slight difference between the efficiency of an earth-furnace competent to keep that shell liquid for a time and the efficiency of an earth-furnace which kept the thermal gradient and solution (fusion) curve "identical" (Chamberlin) within the globe. The identity of these two curves could persist only through a balance between heating and cooling, a balance incredibly delicate in view of the suggested origin of the planets.

Making the more probable deduction from Chamberlin's cosmogenic scheme—an earth once largely fluid from the surface downwards—the facts of geology are better understood. Among the leading facts are: (1) the density stratification of our planet, induced by early gravitative differentiation in gas or liquid; (2) the dominance of gneiss and granite in the early

[9] R. A. Daly, "Igneous Rocks and Their Origin," New York, 1914.

pre-Cambrian complexes, which represent the rearranged material of the earth's primitive crust (a surface differentiate of low density); (3) the dominance of basalt in fissure eruptions, with other facts indicating the existence of a world-circling basaltic *couche* below the crust (the upper layer of Suess's "Sima"); (4) the genetic connection between geosynclinal downwarping and mountain-building with igneous eruption; (5) the number, lengths, and wide distribution of dikes of uniform, diabasic composition; (6) the subsidence of the floors beneath major volcanic masses and of the floors beneath the greater laccoliths; (7) certain stress-strain relations of the earth, since the high rigidity of the earth, for example, may be partly due merely to primitive differentiation according to gravity.

It may be added that the composition of the ocean ought to be quite different, if the ocean began its long life when the earth's mass had only one third or one half its present value. For, by hypothesis, the earth then had an atmosphere, rock-weathering was under way, and river salts were pouring into the ocean. Also by hypothesis, the subsequent growth of the earth was very slow. During that long accretional period, the soluble sodium must have entered the oceanic solution, most of it to remain there to this day. As a matter of fact, the sodium content of sea-water is now embarrassingly low if the earth is no older than the visible pre-Cambrian terranes!

Applied to the earth's later history, the planetesimal-nebula hypothesis thus appears to overlap the gas-nebula hypothesis. In each case a fluid state for the earth is fairly deducible from the astronomic premises. Since the objective facts of astronomy and of geology, especially igneous geology, point in the same direction, the assumption of primitive fluidity seems to be the best working hypothesis on which geology can be based. Meantime, our profound ignorance of the behavior of silicate and metallic melts at very high temperatures and pressures should prevent fixed opinion concerning the cause of the earth's high rigidity. Similarly, the mystery attaching to the original potentialization of energy in the radioactive elements makes uncertain the true relation of radioactivity to the earth's internal heat. As critical facts are slowly accumulated, the greatly appealing planetesimal hypothesis of Chamberlin and his co-workers may well serve as a foundation for geological philosophy, though the subsidiary doctrine of essential crystallinity for the earth throughout geological time be not accepted.

THE MECHANISM OF EVOLUTION[1]

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VI. The Cellular Basis of Evolution

IN sexual reproduction which is well nigh universal among animals and plants adult organisms can give rise to other adult organisms only through the germ cells, and just as the germ cells are the only living bond between generations, so also they are the only living bond between species. Hereditary likeness and specific constancy are due to the persistence of germinal organization; hereditary variation and evolutionary changes are caused by changes in this germinal organization.

1. *Modifications of Cytoplasm*

Of all portions of the germ cells the cytoplasm undergoes the most extreme modifications. The remarkable changes which it passes through in the course of embryonic differentiation have been referred to in preceding pages; but while these changes constitute the sum and substances of individual development they do not affect heredity or evolution. It is certain that the cytoplasmic differentiation of nerve, muscle and gland cells have no direct influence upon the hereditary constitution of the germ cells and it is very doubtful whether the cytoplasmic differentiations of the germ cells themselves affect their hereditary value. The highly differentiated cytoplasm of the spermatozoon has apparently no influence even on the development of the egg which it fertilizes and while differentiations of the cytoplasm of the egg do control some of the most important orientations of development there is no satisfactory evidence that these differentiations are not the result of the environment or of the activity of chromosomes during early stages in the formation of the egg.

The only cytoplasmic modifications or mutations which could be of evolutionary significance would be those which might be transmitted to other generations through the cytoplasm of the germ cells and chiefly through that of the egg cell. One such type of cytoplasmic transmission, which must however have played a very small rôle in evolution, is found in living bodies such as plastids, symbionts or parasites which live and multiply

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 17, 1917.

in the cytoplasm and are carried from one generation to another in the cytoplasm of the germ cells.

On the other hand the orientations of the egg cytoplasm initiate and to a large extent determine the character of all the orientations of development and if it could be proved that the polarity, symmetry, or pattern of localization of the cytoplasmic substances of the egg are carried over from generation to generation, modifications of these differentiations would be of profound influence in evolution. I have elsewhere shown that such a marked modification as the total reversal of the symmetry of the body can be traced to a reversal of the symmetry of the cytoplasm in the unsegmented egg and that changes in the orientation of organs and systems such as are found in vertebrates as contrasted with invertebrates can be most readily explained by tracing them back to changes in the localization of formative substances in the cytoplasm of the egg. The problem of the origin of one phylum or type from another has always involved as one of its chief difficulties such changes in orientation and localization and in a previous section we have seen how earlier evolutionists blundered in attempting to explain how one developed animal might be transformed into another by turning it upside down or inside out. Such changes which are utterly impossible in developed organisms might readily be brought about by relatively slight changes in the cytoplasmic localizations of the unsegmented egg.

Furthermore the integrating and coordinating factors in ontogeny and phylogeny are no less important than the differentiating factors; indeed in some regards they may be said to be more important for without these not only development and evolution would be impossible but organisms would cease to be organized and life would cease to exist. At present we know that many of the integrations of development can be traced back to the polarity, symmetry and localization pattern of the egg cytoplasm. If these differentiations and integrations of the cytoplasm are carried over from generation to generation, then modifications of them must be a very important process of evolution. On the other hand if these differentiations arise anew in each egg cell, as do the various differentiations of tissue cells, through the interaction of nucleus, cytoplasm and environment. then evolutionary changes in orientation may find their ultimate causes in changes in the nucleus rather than in the cytoplasm.

Certain changes in polarity, symmetry and localization of formative substances in eggs may be brought about experimentally by subjecting them to strong centrifugal force but such changes are usually of a temporary character and in no

instance have subsequent generations been studied to find whether these changes are ever inherited. Lang has shown that inverse symmetry in the snail *Helix pomatia* may occasionally appear in normal dextral stock, but that sinistral parents almost invariably give rise to dextral forms; in general there seems to be no regular rule of inheritance of this character. It may be indeed that inverse symmetry is not inherited at all but is the result of environmental causes.

Therefore in the present state of our knowledge there is not sufficient evidence to conclude that modifications of the cytoplasm of germ cells are ever really inherited or that they are ever the initial steps in evolution.

2. *Modifications of Chromosomes*

We have already considered the evidences that the germinal organization which is primarily concerned in hereditary constancy or variation is found chiefly if not entirely in the chromosomes. Evolution therefore involves the problem of changes in the chromosomes or in the units which make up chromosomes, such as chromomeres and genes. Weismann maintained that germplasm must be in a high degree (*a*) stable, (*b*) distinct, (*c*) continuous. The chromosomal organization is more stable than the cytoplasm which undergoes many changes during ontogeny, while the chromosomes usually remain unchanged. The chromosomes being located within the nucleus and the nucleus within the cell-body are protected from extrinsic influences more than the cytoplasm. Furthermore they are relatively distinct from the cytoplasm and they are continuous from cell to cell and from generation to generation.

Undoubtedly modifications of chromosomal organization may and do take place. Only the grosser modifications can be seen directly, while many others must be inferred from physiological responses such as the results of development. Most of the visible changes which take place in chromosomes occur during mitoses while intermitotic stages are relatively more stable. Slight chemical, thermal or osmotic changes in the medium may produce extraordinary modifications of mitoses, whereas during resting stages changes many times as great may produce no visible or lasting effects. Almost all of the experimentally produced changes in chromosomes which are known to persist occur during mitoses, while those which are produced during intermitoses are, with one or two exceptions, relatively unimportant and temporary. This may be due to the fact that the chromosomes of mitotic stages are bodies which may be counted and in some cases individually identified, whereas during inter-

mitoses it is difficult if not impossible to count or identify them. Since most of the visible modifications of chromosomes are seen as changes in their size, shape or number it is evident that these modifications could be seen only during mitosis. Many of these modifications are due to abnormalities in the division or separation of chromosomes and such abnormalities are necessarily limited to mitotic stages. Of course the chromosomes are not absolutely removed from the influence of external changes at any time but any influences that reach them during resting stages must come through the cell membrane, the cytoplasm and the nuclear membrane, whereas during mitosis the nuclear membrane is lacking. And in addition to this form of protection from external influences the chromosomes are more solid and consequently less easily changed than the surrounding plasma. But the principal reason why chromosomal changes occur during mitosis is to be found in the fact that the movements which accompany mitosis are interfered with so that division or separation of chromosomes does not take place normally.

Changes in resting nuclei due to the volume or quality of the cytoplasm or to chemical or physical changes in the medium are usually of a temporary nature and have no evolutionary significance. Variations in the volumes of chromosomes are dependent upon the volume of the resting nucleus and this upon the volume of fluid cytoplasm. These variations have no hereditary or evolutionary value as is evident from a comparison of the nuclei and chromosomes of ova and spermatozoa which differ greatly in volume but not in value.

Abnormalities in the conjugation (synapsis), separation (reduction) and distribution (equational division) of chromosomes are much more permanent and important. The two former occur only during the growth and maturation of the germ cells;[1] the last named may occur at any stage during the life cycle and in any cells of the organism, but if any abnormality is to affect the next generation it must be found in the "germ track" (germ-cell lineage). It is not surprising that modifications in the constitution or number of chromosomes are peculiarly liable to occur in the maturation stages in view of the fact that during these stages several complex processes occur which are usually lacking in ordinary mitoses. Among these are (*a*) synapsis or the union of homologous chromosomes from the two parents into pairs, the subsequent splitting of each member of a pair and the condensation of the four "chromatids" thus formed into one "tetrad" (Fig. 12, p. 274); (*b*) reduction or

[1] Metz has found that maternal and paternal chromosomes are paired in every mitosis in *Drosophila* and some other insects.

the separation of whole chromosomes of each pair and their movement to either pole of the mitotic figure (Fig. 17, p. 283); (*c*) the occurrence of two maturation divisions without the intervention of a resting stage by which the four "chromatids" of each tetrad are distributed to four different cells (Fig. 22, p. 389). As a matter of fact most of the persistent modifications of chromosomes which have been discovered hitherto appear during maturation stages.

(*a*) *Changes in Chromosome Number.*—The typical chromosome number may be more or less permanently changed and the developed organism may be greatly modified by non-disjunction of synapsed chromosomes, as Bridges has demonstrated (see p. 287). Probably many other cases in which the number of chromosomes and the characters of the developed organism are atypical may be caused by non-disjunction. For example it is known that *Œnothera lamarckiana* has typically 14 chromosomes in the zygote and 7 in the gametes, but the mutants *O. lata* and *O. scintillans* have 15 chromosomes (Gates, Lutz); the half-mutant, *O. semigigas*, has 21 chromosomes (Stomps), while the mutant, *O. gigas* has 28 (Gates). A likely explanation of the condition found in *lata* is that non-disjunction occurred in one pair of chromosomes of one gamete, whereas in *semigigas* it occurred in all the pairs of one gamete, and in *gigas* in all pairs of both gametes, and in this connection it is significant that *lata* has appeared many times, *semigigas* several times and *gigas* but twice.

Similar modifications of the typical number of chromosomes have been found in a considerable number of plants and animals. For example in *Ascaris megalocephala*, var. *univalens* there is 1 chromosome in each gamete and 2 in the zygote; in var. *bivalens*, which is otherwise indistinguishable from *univalens*, there are 2 in each gamete and 4 in the zygote. A similar case occurs in the sea-urchin *Echinus microtuberculatus* where 18 chromosomes are found in some individuals and 36 in others. The reduced number of chromosomes in a gamete is the *haploid* number; the usual number in a zygote is *diploid;* if an unreduced gamete and a reduced one conjugate the number is *triploid;* if two unreduced gametes unite the number is *tetraploid.* The triploid and tetraploid numbers are probably due to non-disjunction of all the chromosome pairs of one or of both gametes at the reduction division or to the failure of all the daughter chromosomes to separate in some of the ordinary divisions of the germ track. Both triploidy and tetraploidy have been repeatedly seen in many different plants and animals and in general they lead to gigantism, not only the entire or-

ganism being larger than normal but also the individual cells and nuclei.

It is well known that unusual chromosome numbers may result from hybridization of two forms having an unequal number of chromosomes. Thus Herla found that when the two varieties of *Ascaris megalocephala* were crossed, *univalens* having one chromosome in each gamete and *bivalens* two, the hybrid had three; and in all cases of hybrids the number of chromosomes in the zygote is the sum of those present in the two gametes. The same is true when more than one spermatozoon fertilizes an egg. Thus Boveri found that 54 chromosomes are present in a doubly fertilized sea-urchin egg, when each of the gametes contains 18 chromosomes. But since each spermatozoon brings into the egg a centrosome which quickly divides into two there is usually formed a four-poled spindle (tetraster) and the daughter chromosomes are distributed unequally to these four poles and to the four cells into which the egg divides. In general he found that those cells which contained a full haploid set of chromosomes developed normally while those which received less than a full set developed abnormally.

Spindles with three or four poles (triasters, tetrasters) and with double the normal number of chromosomes may result from the failure of the cell-body to divide following the mitotic division of the nucleus, and if centrosomes and chromosomes continue to divide while the cell-body remains undivided a great number of centrosomes (polyasters) and of chromosomes may be found in one cell. Whenever more than two centrosomes are present the chromosomes are almost certain to be unequally distributed to the poles of the mitotic figure, and to the daughter cells if the cell-body divides. Sometimes chromosomes are scattered along the mitotic spindle and do not move to its poles, so that when the daughter nuclei are formed these scattered chromosomes are left out in the cell and are ultimately lost. In all of these cases irregularities in the number of chromosomes are due to abnormalities of the mitotic apparatus by which the separation of daughter chromosomes is effected.

On the other hand variations in the number of chromosomes are not always due to non-disjunction at the reduction division nor to the failure of daughter chromosomes to separate in ordinary mitoses, as is shown by the fragmentation of the chromosomes of somatic cells in Ascaris, the pig and in *Œnothera scintillans* (Hance, p. 395), and also by the fusion of chromosomes into compound ones called by McClung "hexads," "decads," etc., as in some insects. In these cases it is certain

that the unusual numbers are not due to non-disjunction but rather to a fragmentation or to a fusion of chromosomes. Metz has found that in different species of *Drosophila* the number of chromosomes varies from 6 to 12 depending, apparently, upon fragmentation or fusion of original chromosomes. In cases of fragmentation or fusion of chromosomes the quantity of chromatin and presumably the number of chromomeres remains the same. Consequently changes in the number of chromosomes caused by fragmentation or fusion represent merely changes in the grouping of chromomeres and not changes in the constitution of the hereditary material.

Abnormalities in the distribution of chromosomes of a cell persist in all its daughter cells and are not usually corrected. On the other hand abnormalities in the distribution of cytoplasmic substances to the cleavage cells frequently occur and usually the cell returns to a normal condition by a process of regulation. But when once the normal number of chromosomes has been changed there is no regular means of restoring that number. Momentary changes in the temperature, density or chemical composition of the medium may thus produce permanent changes in the distribution of chromosomes and of germplasm. Such changes in the distribution and number of chromosomes are usually of so gross a character that the development is not only very abnormal but also the resulting organism is incapable of continued life and reproduction. Consequently such changes do not usually give rise to new races or species; only in the most favorable cases where at least the full set of haploid chromosomes is present does the new form survive and reproduce.

Although abnormality in chromosome number is found in some mutants it is by no means certain that this abnormal number is the cause of mutation and there are some good evidences that it is not. For example, deVries finds that the tetraploid number in *Œnothera lamarckiana*, mut. *gigas* is a result rather than a cause of this mutation. *Gigas* is not merely a tetraploid *O. lamarckiana* but a true mutation in which the tetraploid number of chromosomes is one of the new characters. Stomps confirms this conclusion of deVries; he finds in *O. lamarckiana* and in *Narcissus poeticus* that the *gigas* condition may occur with or without doubling of the chromosomes; Gregory has found the same thing in *Primula sinensis*. Therefore in those *gigas* mutants in which the number of chromosomes is doubled we can not conclude that this is the cause of the mutation.

A similar condition is found in those animals in which the male has one less chromosome than the female; it has sometimes

been assumed that the sex is caused by the number of chromosomes, and yet in many species the male and female have the same number, the sex chromosomes in one case being known as *XY* and in the other as *XX*. Morgan and his co-workers have shown that it is not the *number* of chromosomes which determines sex but the *kind* of chromosomes. This case bears directly upon the supposed relation between chromosome number and evolution, for the differences between a male and a female of the same species are frequently as great as those between two different species; indeed males and females might be regarded as mutants, were it not for the fact that both forms recur in every generation because of the recurrence of male and female chromosome combinations.

(*b*) *Changes in Chromosome Constitution.*—But just as sex differences are not always associated with a difference in the number of chromosomes, but often with differences in size or constitution of particular chromosomes, so mutants do not always nor even usually have different *numbers* of chromosomes though particular chromosomes probably differ in quality in different cases. Janssens discovered that chromosomes of a synaptic pair may twist around each other and he inferred that when they separate in the reduction division sections of the two may have interchanged places. Robertson and Wenrich have described a more complicated form of "crossing-over" due to a longitudinal splitting of each chromosome of a synaptic pair, the condensation of these four chromosomes into a tetrad and the subsequent separation of these in such a way that chromosomal interchange takes place. Morgan and his associates have shown that many important changes in the linkage of characters which are inherited in groups may be explained by this "crossing-over" of sections of homologous chromosomes (see p. 289).

But changes in chromosomal constitution are rarely directly visible, although they may be inferred from the results of development. By the study of Mendelian ratios Shull has shown that in certain cases a particular gene is duplicated in certain gametes. He points out that such "duplicate genes" could be caused by the synapsis of non-homologous chromosomes or by the transfer of part of one chromosome containing such a gene to another non-homologous one. In the former case the chromosomal grouping would be changed so that each gamete would contain two homologous chromosomes; according to his second hypothesis the *constitution* of two chromosomes would be modified, namely the one from which the gene in question was removed and the one to which it became attached. Bridges also

has shown that there is genetical evidence that sections of one chromosome may in some cases be joined to another non-homologous one, and the cytological evidence shows that in certain cases chromosomes undergo fragmentations, in other fusions, and that a chromosome is not invariably composed of the same chromomeres. Bridges has described a phenomenon in *Drosophila* which he calls "deficiency" and which consists in the elimination (or inactivity) of certain closely linked genes, probably as the result of the dropping out (or the inactivation) of a section of a chromosome.

(*c*) *Experimental Modification of Chromosomes.*—Experiments on dividing cells show that chromosomes, like all forms of protoplasm, may be modified, injured or destroyed by various chemical substances, by increasing or decreasing the density of the surrounding medium, by increasing the temperature slightly above the optimum, by an electric current, X-rays, radium, etc. Such experimental conditions also cause very abnormal separation and distribution of the chromosomes in mitosis.

Such modifications of chromosomes either stop development altogether or they produce profound monstrosities which usually bring development to an end at an early stage. In few if any cases has it been possible to carry such abnormal forms to maturity and in no instance has any one been able to study the effects of such modifications of chromosomes on subsequent generations. Evidently experimentally produced modifications of chromosomes which are large enough to be visible with the microscope are usually too great to allow of their being carried over to another generation. However Plough has found that high temperature acting on the early oocyte stage of *Drosophila* increases the number of cross-overs and of course such changes are transmitted to subsequent generations; here is indirect evidence of the fact that the constitution of chromosomes may be modified and direct evidence that genetical constitution may be changed by environmental influences acting on the germ cells at an early stage. Probably many other changes in the constitution of chromosomes may be traced to environmental influences; if so initial stages in evolution may find their causes in such influences.

3. *Changes in Genes*

Although some inherited variations are caused by changes in whole chromosomes or visible portions of chromosomes, by far the larger number of such variations show no such visible causes. Nevertheless there is evidence that such variations are caused by changes in invisible units or genes which are

located in the chromosomes. Reasoning from the seen to the unseen, from chromosomes to genes, we are justified in concluding that the behavior of the two is comparable, except that in general the simpler a unit is the more stable it is. Chromosomes are more stable than cytoplasm but genes are probably much more stable than chromosomes. We have seen that chromosomal organization may be modified: (1) by changes in number or combination due to the omission or addition of whole chromosomes, (2) by changes in constitution due to new combinations of the parts of which chromosomes are composed. It seems probable that genes also may be modified in these two ways.

(*a*) *New Combinations vs. New Constitution of Genes.*— The genetical evidence proves that entire genes may be transferred from one chromosome to another as in "cross-overs" or "duplicate genes" and that entire genes may be lost or rendered inactive as in "deficiency." In this way new combinations of genes are formed which lead to important changes in heredity and development and which may become initial stages in evolution. Furthermore it is highly probable that individual genes, in some cases, undergo a change in constitution owing presumably to fragmentation or new combination of the parts of which they are composed. In this connection it is interesting to recall that Darwin recognized two kinds of variations, (*a*) those caused by changes in the number of pangenes and (*b*) those caused by changes in the pangenes themselves ("Variations," Vol. II., p. 390). DeVries also made this distinction at an early date, in his "Intracellular Pangenesis" (pp. 73, 210). In the conception of deVries either of these changes are mutations; on the other hand Morgan and his school look upon mutations as changes in the constitution of individual genes, while new combinations of genes are not regarded as mutations in a strict sense.

The most important work on mutations and their causes has been done by deVries on the evening primrose, *Œnothera lamarckiana*, and by Morgan on the pomace fly, *Drosophila melanogaster*. In the former more than a score of mutants have been discovered and studied genetically, since 1900, in the latter more than 150 since 1910. Several geneticists, notably Johannsen, Heribert-Nilssen, Lotsy, Davis and Bateson, maintain that there is no sufficient evidence that *Œnothera lamarckiana* is a homozygous or pure form and they hold that the mutations described by deVries are the results of Mendelian segregation from this impure stock. This conclusion has now

been demonstrated by Shull in the most satisfactory manner. The fact that such mutations occur only rarely and that they do not exhibit Mendelian ratios may be explained by the partial or complete sterility of certain gametes or zygotes, for in this genus there is much sterile pollen and many seeds fail to germinate. In *Drosophila* a large number of lethal factors have been discovered which cause the early death of zygotes in which they are not balanced by normal factors. In *Œnothera* also such lethals probably cause the death of certain classes of gametes and, if only those gametes which are different in the two sexes survive, the species will remain constantly heterozygous. In such a case if certain recessive factors are linked in the same chromosome with lethal ones they could come to expression only when by crossing-over this linkage was broken, and it seems probable, as Muller has said, that many mutants of *Œnothera* "are merely the emergence into a state of homozygosis, through crossing-over, of recessive factors constantly present in the heterozygous stock." Of the nine mutants of *O. lamarckiana* which were first discovered by deVries no less than five (viz., *lævifolia, albida, oblonga, rubrinervis* and *nanella*) are probably due to such cross-overs; three are possibly due to alterations in the usual number of chromosomes (viz., *lata, scintillans* and *gigas*) though the most recent work indicates that this is not the real cause of these mutations; while one (*brevistylis*) is evidently due to a change in a particular gene. If this interpretation is correct the *development* or appearance of all of these mutants depends upon a particular combination of dominant or recessive genes, though only in the last named mutant does this follow the rule of simple Mendelian segregation. But granting all this we explain only the peculiar manner of *segregation* of dominant and recessive factors in *Œnothera* and we find no explanation of the *origin* of such factors; the real problem after all is to explain how a dominant factor may give rise to a recessive one or *vice versa*. Here it seems logically necessary to assume that the individual factor undergoes some chemical or physical change. Peculiar combinations of dominant and recessive genes will explain the development of such mutants but not the origin of peculiar genes.

(*b*) *The Dogma of Immutable Genes.*—It is known that genes are relatively very stable; they may be carried along unchanged through hundreds of generations and thousands of individuals. Morgan calculates that there must be at least 7,500 genes in *Drosophila melanogaster* and yet in some hun-

dreds of generations and many thousands of individuals he has found only about 150 mutant types although *Drosophila* seems to be mutating more rapidly than most species. The constancy of some species can be measured not only in years but even in geological ages and the constancy of some characters must be greater than that of a species, while the constancy of genes in general must be even greater than that of characters.

This relative stability has given rise to a dogma that genes are immutable and that all changes in the material basis of heredity are caused by new combinations of the same old genes; Lotsy in particular holds this view. It is interesting from the historical standpoint to recall that immutability has been ascribed to (1) species (Linnæus), (2) elementary species (Jordan), (3) pure lines (Lotsy), (4) unit characters (de-Vries), (5) germplasm (Weismann's earlier work), (6) genes (Lotsy). Immutability, like spontaneous generation, has sought refuge successively in smaller and smaller units but there is no reason to suppose that these smallest units of living matter are changeless. Indeed neither molecules nor atoms are now supposed to be absolutely changeless. In general the stability of any unit is proportional to its simplicity; no units of living matter are absolutely simple and therefore none is absolutely stable.

We know that species, subspecies, pure lines, persons, cells, chromosomes are subject to change. Genes are at the least very complex molecules and it is incredible that they are immutable or absolutely removed from influences of external or internal environment. The dogma of immutable genes leads logically to the position taken by Lotsy, namely, that there is no real variation, no actual evolution, no genuine progress; in short to a philosophical system of negations which is contrary to experience both in its assumptions and conclusions.

What are Genes?—As long as these units are not identified as material bodies it is possible to invest them with all the properties we are trying to explain and thus to shift the problems of heredity and evolution to a more inaccessible field. To a certain extent this has been done by Weismann and his followers. In all cases an "explanation" must be in more general terms than the thing to be explained.

Undoubtedly genes are material bodies with chemical and physical properties. Undoubtedly they are capable of growth and division like any other living units, though it is possible that they are not living in a strict sense. Their method of growth and division indicates that they are more than single

molecules and are probably colloidal aggregates of molecules, though their great stability led Morgan at one time (1917) to suggest that they might be single molecules. The fact that they have the power of growth and division suggests that they are autocatalytic substances (p. 276) and their great influence on development in spite of their very small size, as well as their specificity, has suggested to several writers that they are enzymes or bodies which produce enzymes.

(*c*) *Mutation of Genes.*—The fact that genes are relatively complex bodies would indicate that they can not be absolutely stable and wholly uninfluenced by environment, for nothing can be such which is not absolutely simple. Assuming then that genes are at least very complex molecules of protein-like substance and that more probably they are colloidal aggregates of such molecules, we may conclude that they undergo change by dissociation and recombination of the molecules, radicals or atoms of which they are composed. With large and complex molecules enormous numbers of different combinations of the same atoms are possible; thus Miescher calculates that a molecule of albumin with 40 carbon atoms may have as many as one billion stereo-isomers, and in protoplasm there are many kinds of albumin and other proteins, some with more than 700 carbon atoms. Reichert says that serum albumin may theoretically exist in as many as a thousand million forms. Therefore, even if genes are single molecules, it is chemically possible to have an enormous number of variants of each of them, and if they are aggregates of such molecules the number of different kinds which would be chemically possible would be greatly increased. Mutation in genes may therefore be thought of as due to the loss or addition of certain constituent atoms or molecules or to the rearrangement of some of these. But on the other hand the fact that genes are relatively very stable indicates that something other than the possibilities of chemical alteration are involved in their mutations.

It is an interesting fact that many mutations seem to involve the loss of something; very many if not the majority of the mutations which have occurred among domestic animals and cultivated plants are of this sort, such as the loss of color (albinism) in many plants and animals, the loss of glumes or bristles or hairs, etc. Such mutations deVries calls "regressive." On the other hand a few mutations seem to add something which was not present before and these deVries calls "progressive" and he thinks that they are of especial significance in evolution. We must not however conclude that the loss or addition of a character means the loss or addition of a

new gene nor even of molecules or atoms of a gene, for the rearrangement of the parts of a gene may lead to the appearance of new characters just as the rearrangement of the atoms of a molecule may lead to new qualities in a chemical substance. The old idea of evolution by addition of new characters, or by accretion, is out of harmony with what we know of individual development where differentiation takes place by the transformation of units already present and not by additions of new units. Nowhere in the entire process of organic evolution is there any evidence that new genes are "extrinsic additions" or are created *de novo*. When Morgan says: "Evolution consists largely in introducing new factors that influence characters already present" (1917) he can only mean that new combinations of the same old genes are brought about by crossovers, non-disjunction or fertilization, or that new kinds of genes arise by transmutation of old ones through new combinations of the elements of which genes are composed. The whole mechanism of evolution consists in new combinations of the units of organization whether those units be characters, cells, chromosomes, chromomeres, genes, subgenes, molecules or atoms.

Mutants are in the main recessives when mated with their normal allelomorphs, but they are not always recessive as is claimed by Lotsy. Among more than 150 mutants which have appeared in Morgan's cultures of *Drosophila* 12 are dominant or semi-dominant. Many other dominant mutants are known such as abnormally short limbs, fingers and toes, supernumerary digits, hereditary cataract and other eye defects in man, hornlessness in cattle, rumplessness in poultry, red sunflowers, red buds in *Œnothera lamarckiana, mut, rubricalyx, et al.*

Morgan and his school have proved by genetical evidence that a particular gene may change in any one of several different ways, probably owing to various changes in its composition. Thus the gene for the normal red eye color may change so as to give rise to "blood," "cherry," "eosin," "buff," "tinged" or "white" eyes. Genes, or allelomorphs, that mutate in various directions give rise to what are known as "multiple allelomorphs"; hypothetically these may be explained as due to different changes, probably of a chemical nature, in a particular gene. Not only may genes mutate in different directions but some genes apparently mutate more frequently than others, as Emerson has shown in the case of corn and as Morgan has found in *Drosophila*. DeVries especially has long maintained that some genes are more "labile" than others, although more

recent work on *Œnothera* indicates that this so-called lability may be caused by crossing-over, at least in some instances.

Furthermore the same mutation may occur independently in different cultures or even in different species. Thus Morgan says that white eyes have appeared independently in his cultures of *Drosophila* three different times, vermilion eyes six times, rudimentary wings five times, etc. In this case it is known that the mutating gene in each instance named occupies the same locus in the chromosomes and there can be no doubt that each of these recurring mutations is due to the same sort of change in the same gene. DeVries has observed the independent recurrence of the same mutation in different cultures of *Œnothera*, and other investigators have noted a similar phenomenon in other organisms; these are probably caused by identical changes in particular genes. The independent recurrence of a mutation must indicate a tendency for a gene to change in a particular way just as chemical changes tend to go in certain directions. A similar cause probably underlies the tendency of organisms to evolve in definite directions—a phenomenon which has been called "orthogenesis" (Haacke, Eimer, Whitman) and which has been especially emphasized by paleontologists.

Not only do the same mutations recur within the same species but apparently identical mutations may appear within different species. Metz has shown that certain mutants of *Drosophila virilis* closely resemble corresponding ones in *D. melanogaster* and that in both species the mutating genes are located in corresponding chromosomes; however such cases are exceptional. Albinism, melanism, gigantism, etc., have appeared repeatedly in many different species, and this raises the interesting question whether identical genes may occur in different species and undergo identical changes. While this may be true in some cases it is certainly not true in all. Mutations which look alike may be genetically different; albinism, for example, is recessive in mammals while at least two kinds of albinism occur in poultry, one of which is dominant and the other recessive. White flowers even within the same species may be due to mutations in different genes, as in the case of sweet peas; Morgan has shown that mutants of *Drosophila* which look alike may be caused by mutations of different genes, occupying different loci in the chromosomes. We can not conclude, therefore, that mutations which look alike are always due to similar changes in identical genes.

Mutations of genes may probably occur in any cell, but if

they are to be transmitted to the next generation by sexual reproduction they must take place in the germ-cell lineage at least as early as the maturation stages in the case of dominant or sex-linked characters and possibly much earlier, while in the case of recessive mutations they may occur many generations back and be carried along without giving any sign of their presence until they are mated with a similar recessive mutaiton. In such cases the actual mutation occurs long before it comes to expression in a developed mutant.

(*d*) *Extrinsic Causes of Mutation.*—Various changes in the chemical and physical environment produce abnormalities in the number, distribution and constitution of chromosomes, as was pointed out on a previous page, and it is not antecedently improbable that such environmental changes may produce similar modifications in genes themselves. Nevertheless it must be admitted that at the present time no single case is known in which such environmental changes have certainly produced a mutation in a gene.

Several investigators have described cases in which mutations have been ascribed to the action of external agencies, but in no one of these cases is it certain that the external change produced the mutation in question. One of the first instances of the supposed experimental production of a mutation was described by MacDougal in 1905. He reported that he had injected various solutions, particularly zinc sulphate in different concentrations, into the ovaries of a species of *Œnothera* (*Raimannia*) and had obtained as many as 13 different mutants. A year later he reported that he obtained 3 mutants in a similar way. These results have not been confirmed by other workers and the evidence seems to favor the view that MacDougal was dealing with a naturally mutating stock and that the mutants were not caused by the experimental conditions.

Tower (1906) carried on extensive and prolonged studies on the evolution of the potato beetle, *Leptinotarsa*, and concluded that he had induced mutations in this form by changes in humidity and temperature acting upon the germ cells at a sensitive stage in their genesis, presumably by causing mutations in the genes. But in this case also it is not certain that the mutations observed were actually caused by the experimental treatment and there are many reasons for concluding that they were not.

Many other investigators have studied the injurious effects on development of different experimental conditions acting on the germ cells. Thus Bardeen and O. Hertwig found that when

normal frog's eggs were fertilized by spermatozoa which had been exposed to X-rays or radium the resulting development was very abnormal. Cole found that when lead acetate was fed to rabbits or fowls their germ cells were so affected that they produced abnormal offspring. However in none of these experiments is it known that these abnormalities were heritable, since they were not followed to later generations.

Stockard has made an extensive study of the inherited effects of alcohol upon guinea pigs. He finds that the offspring of alcoholized animals are frequently weak and abnormal and that these effects may be traced to the third or fourth fillial generation. The effects of alcohol on the male germ cells seems to be greater than on the egg cells, and since the portion of the spermatozoon which enters and fertilizes the egg is composed almost entirely of chromosomes it seems reasonable to conclude that the chromosomes have been injured by the alcohol. On the other hand there is no evidence here that individual genes have been caused to mutate and the fact that the injurious effects wear off after three or four generations seems to indicate that the changes produced by the alcohol are not of the nature of mutations. It should be said that Pearl's experiments on the inherited effects of alcohol on chickens do not support Stockard's results; he finds that the offspring of alcoholic parents are fewer in number but stronger than those from normal parents and he concludes that the effect of the alcohol is to kill the weaker germ cells and embryos and to permit only the more hardy ones to survive.

In these experiments with alcohol there is no evidence that genes have been caused to mutate, and indeed there is no satisfactory evidence that the defects observed in the offspring of alcoholic guinea pigs were really inherited. It is known that many environmental influences, such as food, temperature, soil, etc., may modify the development of the first and even the second succeeding generation and then disappear, as Whitney has shown in the case of Rotifers, Woltereck in *Daphnia* and Harris in beans. Such temporary modifications are not really inherited and are known as "induction" phenomena. They do not represent modifications in heredity but rather in development, not mutations in genes but possibly alterations of the cytoplasm.

In conclusion it may be said that although it is certain that mutations of genes take place and although it is highly probable that these mutations, like all chemical and physiological processes, are affected by environmental conditions, neverthe-

less we do not know what the conditions are which induce mutations and at present we are unable to initiate or control them.

(*e*) *Intrinsic Causes of Mutation.*—The failure to find definite extrinsic causes of mutation has led certain students of the subject to conclude that all changes in genes are due to intrinsic causes. The gene has been compared to the radium atom which undergoes disintegration wholly uninfluenced by temperature or other physical or chemical conditions. But, as has been indicated, the gene is not an atom but at the very least an extremely complex molecule and it is incredible that it should be wholly removed from environmental influences, since this is true of no other molecule or group of molecules.

We have no more direct knowledge regarding the intrinsic causes of mutation than concerning the extrinsic ones and yet we may safely assume that certain general principles which apply to visible portions of the organism are true of invisible genes. As development or any physiological process is the response of an organism to various stimuli, so we may assume that mutations also represent the response of the hereditary organization to certain stimuli; and just as the nature of any response is primarily determined by the nature of the organism while the stimuli serve merely to initiate, hasten or retard the response, so the nature of a mutation is probably definitely limited by the organization of the germplasm while its extrinsic causes serve only to initiate or retard it. With true insight Charles Darwin wrote many years ago:

> Although every variation is either directly or indirectly caused by some change in the surrounding conditions, we must never forget that the nature of the organization which is acted on essentially governs the result.

Some conceivable mutations never become real because of these intrinsic limitations. "Whales never produce feathers, nor birds whale bone," said Huxley; and probably no one ever really saw a green horse or a purple cow.

Mutations can not therefore take place in all conceivable directions, owing to the limitations of the organization of the germplasm and these same limitations may sometimes cause mutations to follow more or less closely in particular lines, as for example in the independent recurrence of the same mutation, but on the other hand the organization of a gene is so complex that it may undergo many different alterations, as is shown in cases of "multiple allelomorphism." There is no justification therefore for extreme views of orthogenesis which regard mutations as taking place only in a single direction.

Another hypothesis which is the result of a too extreme insistence on the intrinsic factor of mutation is found in the view that all mutations of genes are in the nature of losses or disintegrations more or less comparable to the disintegrations of the radium atom. The "presence and absence" hypothesis assumed that dominant characters are due to the presence of a factor and recessive character to its absence, and since regressive mutations, in which some dominant character becomes recessive, are much more numerous than progressive ones, it was suggested by Shull, Bateson and Davenport that evolution might be due to the loss or disintegration of factors or genes. "This conception results," said Shull (1907), "in an interesting paradox, namely the production of a new character by the loss of an old unit," and he suggests that at least the later stages of evolution may be a process of analysis due to the disappearance of one unit after another. Bateson (1914) also proposed the same thing in his well-known inquiry "whether the course of evolution can at all reasonably be represented as an unpacking of an original complex, which contained within itself the whole range of diversity which living things present"; and in the same category is the speculation by Davenport that "the foundations of the organic world were laid when a tremendously complex molecule, capable of splitting up into a vast number of simpler molecules, was evolved." But the speculation that a recessive character is due to the absence of a factor has been disproved by work on multiple allelemorphs for here although there may be several kinds of recessives to the same dominant allelemorph there can be only one kind of absence. Furthermore this hypothesis of evolution by degredation offers no real explanation of evolution, but like the old doctrine of preformation it merely puts the mystery back into the supposed causes.

But apart from the fact that this hypothesis of evolution by disintegration offers no real explanation of evolution, it does not at all conform with what we know of other natural phenomena. In the inorganic world, as well as in the organic, changes involve not merely breaking down but also building up, not merely analysis but also synthesis. Everywhere in the living as well as in the lifeless world disintegration is balanced by reintegration. Chemical changes are the results not only of dissociation but also of recombination. In embryonic differentiation new structures and functions arise not merely by a process of disintegration of the structures and functions of the egg and a sorting out of these fragments to different cells, but also by the transformation of the germinal structures and func-

tions into those of the developed organism by a process of recombination or "creative synthesis." Similarly in phylogeny new types, new characters, new genes, arise by the transformation of those already present by a process which may be called "creative evolution."

In conclusion we find that it is impossible to avoid the conviction that the initial stages in evolution are caused by new combinations of chromosomes, chromomeres, genes or subgenes, and that these new combinations take place in response to stimuli from the external or internal environment. Probably experimental cytologists have already made many such new combinations which might have given rise to new species, genera or even phyla if they could have survived. Unfortunately almost all of these changes in the germplasm have been of so gross a character that the new forms were unable to live beyond the early stages of development, and the more extreme they were the earlier they perished. Germ cells are so complex and are so delicately adjusted and balanced that they can not usually be greatly changed without rendering them incapable of continued life. Experimentalists have aimed to produce changes in germ cells or embryos which could be seen with the microscope, but it will be necessary to produce smaller and more subtle changes in the germplasm if we are to determine their effects on succeeding generations. The future may show us methods of modifying the germplasm, more delicate and effective than any that have been discovered as yet, and when that time comes, if it ever comes, a real experimental evolution will be possible.

The mystery of mysteries in evolution is how germplasm ever became so complex as it is, so well adapted to give rise to viable organisms, so filled with the marvellous potencies of development. The greatest problem which confronts us is no longer the mechanism of evolution but the evolution of this mechanism. This problem has been shifted from the developed organism to the germplasm, but has not been solved.

STATE PARKS IN IOWA

By Professor L. H. PAMMEL

IOWA STATE COLLEGE

THE thirty-seventh general assembly of Iowa passed a comprehensive state park bill in the following section of the law:

> The State Board of Conservation, by and with the written consent of the executive council, is hereby authorized to establish public parks in any county of the state, upon the shores of lakes, streams or other waters of the state, or at any other places which have by reason of their location become historic or which are of scientific interest, or by reason of their natural scenic beauty or location become adapted therefor, and said Board of Conservation, under the supervision of said executive council, is hereby authorized to improve and beautify such parks. When so established they shall be made accessible from the public highways, and in order to establish such parks said executive council shall have the power to purchase or condemn lands for such purposes and to purchase and condemn lands for such highway purposes.

The law also provided that the state executive council designate three persons, who with the curator of the Historical Department shall constitute a Board of Conservation, who shall serve without pay. The original bill provided that the sum of $50,000 be appropriated annually out of fees obtained from hunters' license fees. The thirty-eighth general assembly amended this section by making an annual appropriation of $100,000 annually. Thus there came into being a constructive movement for the preservation of regions of historical, scientific and recreational interest.

This movement was of slow growth. More than a quarter of a century ago Dr. Thomas Macbride, of the State University of Iowa, in an address before the Iowa Academy of Science advocated a system of county parks distributed throughout the State; subsequently the Iowa Park and Forestry Association which later became the Iowa Conservation Association, at repeated annual meetings asked the legislature to conserve some of the natural beauty of Iowa. The state park measure has found a hearty response in all parts of the state. The hearty response comes, not only from the cities, but the rural population as well. I like to look upon this movement as a rural movement, because Iowa is essentially a great rural agricultural state. There are no large centers of population. Less than a

VIEW OF THE MAQUOKETA RIVER IN BACKBONE PARK, DELAWARE COUNTY. (Photographed by I. Bode.)

half dozen cities have a population of over 50,000, and only one city has a population of over 100,000.

Those who ride over the state on any of the great transcontinental railways think of Iowa as a state of rolling prairies, devoted to the cultivation of corn and oats, and pastures where fine herds of cattle and sheep graze on the rich bluegrass. Here and there, as the trains cross the valley, one may see small belts of timber. The timbered area is, however, larger in northeastern and southeastern Iowa. Iowa was the center of various ice invasions: the Kansan, Iowan and Wisconsin and a few other minor invasions. These ice sheets shaped the topography of the state, and left the imprints of the floristic features of the region. Let us for a moment consider the most recent of the ice invasions; the Wisconsin, entering the state in Worth county on the east and Osceola county on the west, culminated in Polk county. In this region occur seventy or more lakes, none large, and most of them shallow, with the exception of Lake Okoboji, which is one of the most beautiful lakes in the northern Mississippi valley. In the same county and to the north occurs Spirit Lake, covering a good many hundred acres. In a half dozen counties to the east are many other fine lakes, but all are comparatively small. Curiously enough such lakes as exist in the southern portion of the Wisconsin drift also occur in a tier of counties, to the north of Story, including Hamilton and Sac counties. There were formerly a few very shallow lakes in counties in the same latitude with Story county, one of which, Goose Lake, is so shallow, that it has been ordered drained.

TWO HUNDRED ANE FIFTY YEAR OLD WHITE PINE ON THE MAQUOKETA RIVER IN BACKBONE PARK IN DELAWARE COUNTY. (Photographed by I. Bode.)

In our park system it is hoped to buy areas on the shores of all of the lakes to conserve the animal and plant life and give people generally a chance to make use of these bodies of water. To-day the public can not have access to the lakes, except as trespassers. In the prairie region where these lakes occur there is usually some timber. The state proposes to secure some of these areas. Parks established at these places will be designated lake parks.

WOODS ALONG THE UPPER DESMOINES RIVER NEAR ESTHERVILLE.

A second kind of park to be established will be state parks, such parks to contain large areas along our streams. The first one of these parks to be established, the Backbone Park in Delaware county, contains 1,200 acres. It is situated on the Maquoketa River. The river here has cut through limestone rock more than 100 feet thick. At a point known as the Backbone, or as the old settlers called it, the Devil's Backbone, is a narrow ridge in some cases not more than 50 feet across with the river flowing on each side of it. This park contains some of the original pine trees, some of which are nearly three feet in diameter, and one hundred and sixty to one hundred and seventy years old, some at least two hundred and fifty years old. Growing with the pine are white, chestnut, red, bur and black oaks.

A second park of 1,123 acres has been established in Van Buren county in southeastern Iowa, in a region known as the Horseshoe Bend. This area contains great white oaks 3½ feet in diameter, swamp, white and red oaks. Various forms of animals found in Iowa occur here, like the native pheasant, or drumming partridge, now a rare bird in Iowa; the opossum, the fox, and quail which are found in abundance.

A third park of small dimensions has been established in Henry county on the Skunk River. This park contains some of the primeval sugar maple (*Acer saccharum*), great sycamores and hackberries.

LEDGES IN BOONE COUNTY, ALONG THE DESMOINES RIVER. SANDSTONE CLIFFS 125 FEET HIGH. (Photographed by C. M. King.)

There are under consideration projects for reserves in Boone county in an area known as the "Ledges." These sandstone ledges contain the carboniferous sandstone common along the Des Moines from Webster county south in what is known as the Cedar Bluff region in Mahaska county This area contains an interesting lot of rare ferns.

A Wooded Slope near Kellerton, in Ringgold County, Southwestern Iowa.

There is also under consideration an area in Webster county, known as Woodman's Hollow and Bone Yard Hollow. In Hardin county we have another interesting region known as the Steamboat Rock, Eldora and Alden region. At Steamboat Rock we have not only the most westerly distribution of the white pine, but an abundance of the cherry birch (*Betula lenta*) and the paper birch. The large white lady slipper occurs on the steep slopes of the clay hills.

Two sisters, Misses Clara and Emma Brandt gave to the State 57 acres on Pine Creek in Muscatine county, known as Wild Cat Den. Here may be found such ferns as *Aspidium Goldianum, Phegopteris hexagonoptera, Polypodium vulgare, Pteris aquilina, Pellaea atropurpurea, Camptosorus rhizophyllus, Woodsia obtusa, Osmunda struthiopteris, Onoclea struthiopteris* and *Cystopteris bulbifera.* The region has been protected largely because these two nature-loving women saw the wisdom of keeping for posterity the beautiful things of nature.

There is also under consideration an area in Jackson county, known as Morehead caves, where a natural bridge, which though not as large as the natural bridge of Virginia, rivals it in beauty. Hanging from the walls of the limestone rock are great masses of *Sullivantia ohionis*, *Cystopteris fragilis* and *C. bulbifera*. The cliff brake *Pellaea atropurpurea* was abundant everywhere on the dry limestone rock.

Another area under consideration is the Yellow River area in Allamakee county. This area contains not only the white pine and balsam fir, the latter a very rare tree in Iowa, some two hundred miles out of its range, but many other boreal plants like the little white violet (*Viola blanda*), the high bush cranberry (*Viburnum opulus*), Enchanter's night shade (*Circaea alpina*), *Phegopteris calcarea*, *Aconitum noveboracense*, paper birch, sweet birch (*Betula lenta*) and speckled alder (*Alnus incana*) and the yew (*Taxus canadensis*).

Another area under consideration occurs in what is known as the Palisades in Linn County. Great primeval white oak, the walking leaf fern (*Camptosorus rhizophyllus*), yew, leather wood (*Dirca palustris*), occur in this region. A lot of fine Indian mounds are found here. The state hopes it may place all of these Indian mounds in state parks and Iowa is especially rich in mounds.

In writing about state parks, I should not forget to mention that it is proposed to have a national park or monument on the great and majestic Mississippi River at McGregor, which we hope, will contain several thousand acres and be linked up with our state parks at Waterville, Decorah and the Yellow River. It is far-sighted wisdom that the state of Iowa establish these state parks to preserve to future generations the natural history, geology, and historic features of Iowa.

We also propose to establish highway parks of smaller extent, one or more of these in each county, to be located near some stream, which will serve to preserve the woods, wild flowers, birds and game. We will also consider prairie areas where the wild prairie flowers and animals will be protected.

THE PROGRESS OF SCIENCE

THE NORTHUMBERLAND HOUSE OF JOSEPH PRIESTLEY

JOSEPH PRIESTLEY, born in Yorkshire in 1733, was by profession a dissenting clergyman and carried on his work in science as an amateur. He was led in part by association with Franklin to take up the writing of a history of electricity and to make original experiments in connection with this work, in recognition of which he was elected to the Royal Society and awarded its Copley medal. His remarkable work on gases was carried on while he was acting as a unitarian clergyman at Leeds and Birmingham. He not only discovered oxygen, but also sulphuric and muriatic acid, and did much to enlarge knowledge concerning the properties of oxygen, nitrogen and other gases.

Priestley was not only a liberal in religion, opposed to a state church, but advocated democratic principles of government, with freedom of thought and liberty of discussion. At the time of the French revolution he was made a citizen of France and a member of the assembly. This led to persecution at home, and on the anniversary of the French revolution, in 1791, there was a riot in Birmingham, in which his meeting house and dwelling were burned, and his manuscripts, library and apparatus destroyed. He was even obliged to withdraw from the Royal Society.

Under these conditions Priestley sought freedom in the United States where his sons had already preceded him. Arriving here in 1794, he was received with distinguished consideration by Jefferson and others, the American Philosophical Society presented him with a complimentary address and the University of Pennsylvania offered him a professorship of chemistry. It is said, however, that the alien and sedition law of the Adams administration was

THE PRIESTLEY HOUSE AT NORTHUMBERLAND.

THE PRIESTLEY HOUSE.

passed with some reference to him, and Mr. Adams warned him to abstain from saying anything on politics lest he should get into difficulties.

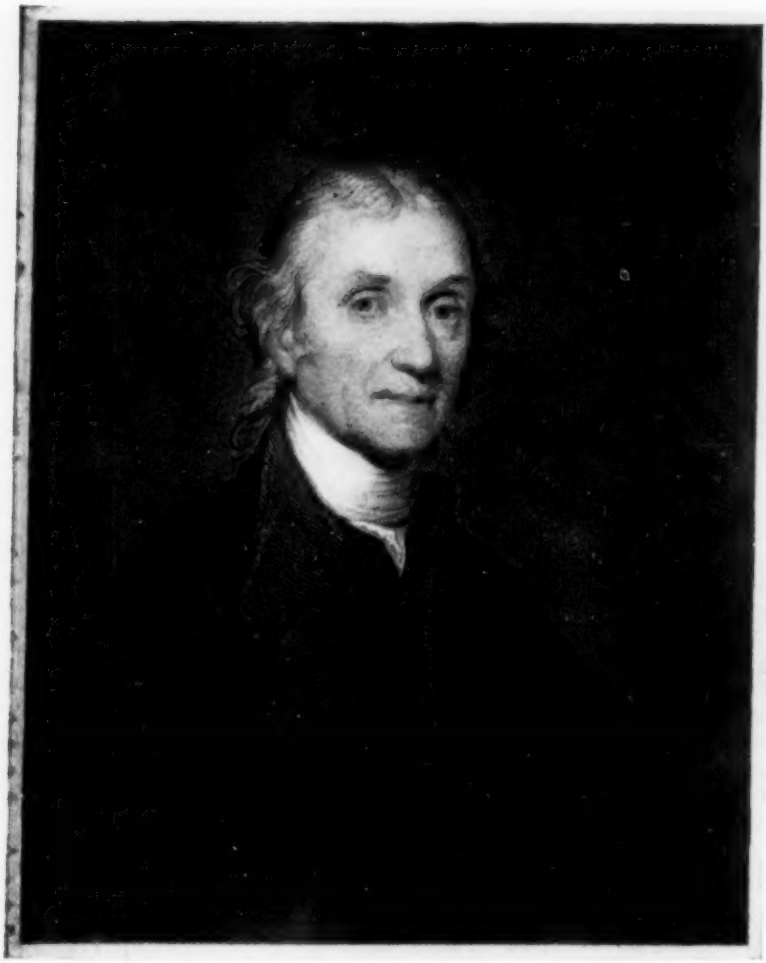
Priestly retired to Northumberland on the Susquehanna river one hundred and thirty miles from Philadelphia, where the house shown in the accompanying illustrations, gave him a library and laboratory. There he worked until his death in 1801.

This Priestley homestead was purchased recently by graduate students of the Pennsylvania State College, who plan to move it to the campus and make it a lasting memorial. Upon learning that the house which was built in 1794–1796, was to be put up at public auction, the Penn State chemists sent as their representative to the sale Dr. G. G. Pond, dean of the School of Natural Science at the college. He was sucessful in making the purchase, and the historic mansion will be preserved.

Architects from the college will make the necessary surveys preparatory to the work of moving the Priestley house to the campus at State College. The house is of frame, and painting has kept the woodwork in a remarkable state of preservation, so that it may be possible to rebuild the greater part of the structure from the present lumber. Immense pine timbers used in the framework are as good as new and the old-fashioned interior decorations—arched doorways, fireplaces and stairway—are in such condition that they can be removed and replaced with comparative ease.

While the purchase of the house has been made for the Penn State chemistry alumni, who are scattered to all parts of the country, funds for its removal and erection on the college campus will be supplied by an as yet unnamed donor. Actual work of removal will probably be started soon. Northumberland is about sixty miles from State College, at the intersection of the north and west branches of the Susquehanna.

The reconstruction on the college campus will be along the old architectural lines, but modernized and adapted to some suitable use by the school of Natural Science, according to present plans. The house is an old landmark in Northumberland county, and can be seen on the



JOSEPH PRIESTLEY.

outskirts of the town from trains on the Pennsylvania Railroad passing Northumberland. It is a two-story structure, with capacious attic space. It is about 45 × 50 feet, with a projection at each end about 25 feet square. One of these was the kitchen and the other the workshop, or laboratory, in which Priestley pursued his scientific study and experiments.

THE WORK IN INDUSTRIAL CHEMISTRY OF THE AMERICAN CHEMICAL SOCIETY

A GROUP of chemists met at Northumberland in 1874 to celebrate the one hundredth anniversary of the discovery of oxygen by Priestley and from this meeting the American Chemical Society had its origin. The society, which now has some 14,000 members and publishes three

important journals, held its spring meeting at St. Louis in April. From a technical point of view the meeting was one of the most helpful and practical ever held by the society. Well-known chemists, who had been active in war work, reported the first fruits of their researches, made since their return to the university and the commercial laboratories. These constitute important contributions to industry and also to the general welfare of the American people.

Several sections of the society dealt with the reduction of the high cost of living in its various phases. The search for vegetable substitutes for meat was shown in papers describing the proteins found in pecans and in Georgia velvet beans. The growing importance of the American beet sugar industry was revealed in a paper on its chemical control. The nature of that invisible and illusive power represented by the vitamines, which are so essential to the quality of food and are destroyed in stale and over-cooked viands, was discussed in papers indicating that the day is at hand when they may be isolated and administered.

Suggestions for the hardening of vegetable oils with the aid of catalyzers, substances which alter the nature of liquid fats through chemical reaction, point the way to the further development of butter substitutes.

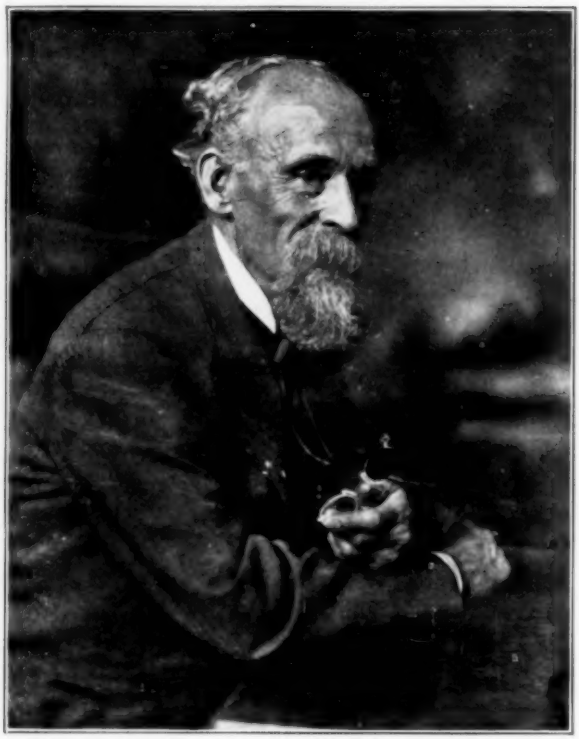
The soft drink industry, which has increased greatly in this country, is making an extensive use of lactic acid, usually derived from sour milk and also obtainable from other sources. The acid is formed by those benevolent bacteria present in the Bulgarian sour milk drinks made famous by Metchnikoff as a means of prolonging life. The use of edible lactic acid and in the potations prohibition has popularized, such as ginger ales and kickless beers, would thus tend to prolong the span of life.

Many persons have come to an untimely death through the drinking of wood alcohol served by bootleggers and unscrupulous dealers, and to shield the public from excess it was proposed before the Pharmaceutical Section that the dangerous liquid be deprived of the name "alcohol" entirely and, following a practise already begun, be known merely as "methanol."

The slogan, "Use American Potash" was sounded by a representative of the United States Department of Agriculture, which is endeavoring to bring this fertilizing element within the reach of every farmer. Experts reported that the American industry need have nothing to fear from the German potash companies which once practically monopolized the trade. The element is now being obtained in considerable quantities as a by-product of the making of cement. The announcement was also made that so many were the by-products obtained in the making of potash from kelp, a giant seaweed plentiful along the Pacific coast, that the kelp-potash industry, with which the government has been experimenting, can now be developed on a profitable basis.

Several papers were read on the feeding of live stock in which suggestions were offered for making the alfalfa, various grasses, silage, and also peanuts more available for animal food.

The extensive experiments made by the Chemical Warfare Service in the preparation of a charcoal rendered porous or activated for use as an absorbent for noxious vapors in the army gas masks, have borne fruit in the development of new industrial uses for this treated material. What with the adapting of the war gas mask for the service of manufacturing and mining, the Chemical Warfare Service, as described in a public lecture given by its head, Lieutenant-Colonel Amos



JOHN ALFRED BRASHEAR

Distinguished as a maker of astronomical and physical instruments and an astronomer, a leader in the scientific, educational and civic life of Pittsburgh, who died on April 9, in his eightieth year.

A. Fries, has made many important contributions to the arts of peace.

The newly constituted Leather Section of the society developed improved processes in the tanning of hides for shoes and for industrial purposes which are likely to greatly increase the efficiency and speed of tanning processes and possibly contribute to a decrease in the prices of footgear. The section devoted to rubber considered a new method of testing that elastic substance with the microscope which is considered revolutionary.

American dyes are able to hold their own not only for the tinting of fabrics but also for scientific and medical purposes, as demonstrated by important papers read before the dye division. A new note appeared in the proposal to derive from corn cobs furfural, which may be used as a base from which to draw dyes, just as certain coal tar products are employed. Thus, furfural green, a favorite tint, may eventually be derived from the refuse of native maize.

MEAT AND MILK IN THE FOOD SUPPLY

THE committee on food and nutrition of the National Research Council has issued a report on meat and milk in the food supply of the nation, which is summarized in a press bulletin of the council.

Dr. Armsby, probably the leading American expert on animal nutrition, has estimated that of the energy of grain used in feeding the

animal there is recovered for human consumption about 18 per cent. in milk, and only about 3½ per cent. in beef. In an official Report on the Food Supply of the United Kingdom, it is estimated that the production of 100 calories of human food in the form of milk from a good cow, requires the consumption of animal feed by the cow of 2.9 pounds starch equivalent; 100 calories milk from a poor cow is estimated to require the consumption of 4.7 pounds; while 100 calories of beef from a steer 2½ years old, is estimated to require the consumption of 9 pounds of starch equivalent in food.

Stated in terms comparable with those used by Dr. Armsby, this would mean that the good milk cow returns 20 per cent. of the energy value of what she consumes, the poor milk cow 12 per cent., and the good beef steer only 6 per cent. Although this estimate is more favorable to the beef steer than is that of Dr. Armsby, yet even by this estimate it will be seen that the poor cow is twice as efficient, and the good milk cow more than three times as efficient as the beef steer in the conservation of energy in the food supply.

Considering the whole length of life of the animal, Professor Wood, the leading English agricultural expert, estimates that the cow returns in milk, veal and beef, $\frac{1}{12}$ as much as she has consumed, while the beef steer returns only $\frac{1}{64}$. In other words, the cow is five times as efficient as the beef steer as a food producer when the whole life cycle of the animal is considered.

Similarly it has been estimated by Cooper and Spillman (Farmers Bulletin, No. 877, 1917, U. S. Department of Agriculture) that the crops grown on a given area may be expected to yield from four to five times as much protein and energy for human consumption when fed to dairy cows as when used for beef production. As Professor Wood has very strikingly shown, the longer the time that the beef animals are fattened on grain, the less economical the process becomes.

But not only is the milk cow several times more efficient than the beef steer in the conservation of proteins, fats and carbohydrate for human consumption, but in the gathering and preparation of mineral elements and vitamines she contrasts even more favorably with the beef animal. It is largely because of its richness in calcium and in fat-soluble vitamine that milk is the most efficient nutritional supplement to bread or other grain products.

SCIENTIFIC ITEMS

WE record with regret the death of George Egbert Fisher, professor of mathematics in the University of Pennsylvania; James Gayley, past president of the Institute of Mining Engineers; James Emerson Reynolds, formerly professor of chemistry at the University of Dublin; Charles Lapworth, for many years professor of geology and physiography in the University of Birmingham; Pier Andrea Saccardo, emeritus professor of botany in the University of Padua, and Woldemar Voigt, the mathematical physicist of the University of Göttingen.

AT a meeting held in the rooms of the Royal Society, to consider the question of a memorial to the memory of Lord Rayleigh, it was agreed that a fund should be raised for the purpose of placing a memorial, preferably a window, in Westminster Abbey. A committee was appointed to consider details and the further question of raising a fund in memory of Lord Rayleigh, to be used for the promotion of research in some branch of science in which he was specially interested.—Dr. Harvey Cushing, Peter Bent Brigham Hospital, Boston, has been requested by

Lady Osler to prepare a biography of Sir William Osler. He will be grateful to any one who will send him either letters or copies of letters, or personal reminiscences, or information concerning others who might supply such information.

THE University of Pittsburgh has conferred honorary doctorates upon Dr. William H. Nichols, retiring president of the American Chemical Society, and Dr. William A. Noyes, present president.

SIR JAMES DEWAR has been elected a corresponding member of the French Academy of Sciences in the section of physics in succession to the late Professor P. Blaserna.

THE National Research Council has appointed a committee on eugenics, under the division of biology and agriculture with Dr. C. B. Davenport, as chairman, and this committee has voted to hold the Second International Eugenics Congress in New York City, September 22 to September 28, 1921 on the invitation of the American Museum of Natural History Dr. Alexander Graham Bell has been elected honorary president and Dr. Henry F. Osborn, president.

PROFESSOR ALBERT A. MICHELSON, of the University of Chicago, has been elected a foreign associate of the Paris Academy of Sciences to succeed the late Lord Rayleigh.—The Academy of Natural Sciences of Philadelphia has awarded its Hayden memorial geological medal to Professor T. C. Chamberlin, of the University of Chicago.—The Bruce Gold Medal of the Astronomical Society of the Pacific has been awarded to Professor Ernest W. Brown, of Yale University.

SIR AUCKLAND GEDDES, formerly professor of anatomy and principal-elect of McGill University, now a member of the British cabinet as president of the board of trade, has been named as British ambassador to the United States.

MR. J. OGDEN ARMOUR has made a further gift of six million dollars to the Armour Institute of Chicago. A new site for the school has been purchased at the cost of one million dollars, and five million dollars will be expended on buildings.—Yale University has received from Bayard Dominick, of the class of 1894, Yale College, gifts amounting to $40,000 for scientific exploration in the Southern Pacific Ocean. Professor Herbert E. Gregory, of Yale, is the active head of the expedition.